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MICHAEL FARADAY, D.C.L., F.R.S. &c.

SIMPLICITY and wisdom have never been combined in human character to a greater perfection than in the case of this illustrious chemist and natural philosopher. To his simplicity was added courage, to his wisdom an almost unlimited power of perception. Spending his life in exploding errors, he always placed in their stead irresistible truth; and while, in most instances, iconoclasm begets hostility, and necessitates a degree of forbearance, he maintained an imperturbable amiableness and an unstained purity. When Tyndall found himself in hot water at Glasgow, in 1855, after reading a paper there, Faraday wrote him a letter exhibiting his own habit of mind under like circumstances. "When I was younger" he says "I found I often misinterpreted the intentions of people, and found they did not mean what at the time I supposed they meant; and, further, that as a general rule, it is better to be a little dull of apprehension where phrases seem to imply pique, and quick in perception when they seem to imply kindly feeling. The real truth never fails ultimately to appear; and opposing parties, if wrong, are sooner convinced when replied to forbearingly than when over-

whelmed. You can hardly imagine how often I have been heated in private when opposed, as I have thought, unjustly and superciliously, and yet, I have striven, and succeeded, I hope, in keeping down replies of the like kind." These are great sentiments, and his whole career proves he felt and practised them.

In a short paper like the present the utmost condensation must be practised, because of the vast quantity of most beneficial and instructive matter associated with his person and labours and the variety of subjects his unceasing activity led him to investigate.

Faraday was the son of a Yorkshire working blacksmith, who had settled at Newington Butts, and was born on September 22, 1791. At the age of thirteen he was apprenticed to Mr. Rilban, a bookbinder and bookseller, in Blandford Street, Manchester Square, where he remained until, at the age of twenty-one, he obtained a situation as a journeyman elsewhere, but kept it only six months. His master was "disagreeable," and the tricks and manners of the business disgusted him so much that he resolved to leave it. When as an apprentice his chief employment was the binding of books, labour threw many good works in his way. He acknowledges gratefully his obligations to "Mrs. Marcet's Conversations," a book familiar to us in our young days, and he tested all his knowledge by the contents of the "Encyclopædia Britannica," to which he added experiments, and what was then a common practice among youths of studious habit, made an electrical machine with a glass phial and afterwards with a cylinder, beside other electrical apparatus. Faraday said he would turn philosopher; Sir H. Davy, then in the zenith of his fame, had been exciting the town with his famous lectures before the Royal Society, and through the kindness of Mr. Dance, one of the members, the young student obtained permission to hear the last of them. In 1812 he took notes, copied them out, and sent them to Sir Humphry, entreating him to help him "to escape from trade and enter into the service of science." Davy was in the habit of calling on Mr. Pepys, in the Poultry, as he went to the London Institution, and one day he said to him, "Pepys, what am I to do? Here is a letter from a young man named Faraday: he has been attending my lectures, and wants me to give him employment at the Royal Institution. *What can I do?*" Davy replied, and by his good offices obtained, on March, 1813, from the managers, a resolution appointing him as a chemical assistant in the room of a weekly servant who had left. When Sir Humphry retired and gave his office to Professor Brande, he stipulated that Faraday should be director of the laboratory, and thereby gave him status; but Davy had become attached to his *protégé*, and on entering upon his celebrated travels through Europe invited him to take the post of his secretary and assistant, which the pupil and friend could not decline. Upon his return in 1815, the managers of the Royal Institution re-engaged him, and his progress in chemistry excited attention. Davy gave him analyses to do, and he soon appeared as a contributor to the Society's papers, and in other ways showed his possession of power. One instance we mention, because no notice or memoir of him contains it. He accepted in 1817 the office of President of the City Philosophical Society, which held its meetings in Dorset Street, Salisbury Square, and read an address on "The Means of obtaining Knowledge." He showed that knowledge in their times was indispensable above all earthly things, for its profits and for its power; that it conferred dignity on an age, that it gave kingdoms their noblest and mightiest distinction, that it immortalized its possessors. He then defined knowledge as an acquaintance with causes, effects, laws, and principles; that the division thereof is not mind and matter so much as moral and material; that it was important to know how to acquire it rather than know *of* it, for it was of no avail until possessed; illustrating it by the variety of objects men place before them, and the variety of motives as well as information involved. In referring to himself he confessed his obligations to Lord Bacon's "Essays" and Watts's "Improvement of the Mind," confessing that his knowledge of authors was very limited, but extolling the habit of association and intercourse. He then offered remarks on the means to that end, speaking warmly of what used to be called "private evenings," where members of such institutions met for conversation on their special subjects of culture; and then propounded his views on lecturing, showing that many might converse but none know; whereas, in lecturing, the lecturer must give correct and undoubted information—that it improved the lecturer as much as the lectured. He passed a high eulogium on books that are carefully written, as the best form of reproducing the knowledge possessed by one for the benefit of all; concluding with some pertinent remarks on the value of observation as the test of all things, and on study as the great digester of whatever may be gathered or collected.

In 1821, while assisting Sir Humphry Davy in pursuing the investigation of the relations between electricity and magnetism, first intimated by Oersted in the previous year, Faraday made the brilliant discovery of the convertible rotation of a magnetic pole round an electric current. This was the beginning of his marvellous discoveries in electricity, which were subsequently (1839-1855) set out in the three volumes entitled "Experimental Researches in Electricity and Magnetism." This result cost immense labour and time. He had seen Dr. Wollaston's experiments with Sir H. Davy at the Institution and read much, which he reproduced, with his own knowledge, in Thomson's "Annals of Philosophy," at the time. The revolution of a magnetic needle round an electric current was witnessed by his wife on Christmas day, 1821, and the discovery made him master of all that was then known regarding the voltaic current.

We will compress his own description of these long series of invaluable papers into a mere outline. They occupy several volumes in their original condition, and remain a treasury for many future years of investigation. He acquired the honour of being elected Corresponding Member of the Academy of Sciences in 1823, and Fellow of the Royal Society in 1825, on account of the earlier portions, and, as we shall see at the close, honours from all whose regard deserved his acceptance came plentifully.

They begin by his examination of Tadder's alleged discovery of caustic lime in an old Italian bath, the water of which he sampled and brought home for analysis. It belonged to the Duchess of Montrose, and after Faraday had completed his analysis Sir Humphry Davy made his report. The contents of the bottle proved to be caustic lime in a native state, and the chemical world were puzzled to know what conditions could have produced such a substance. Davy said that it was the geological agency of carbonic acid which had modified the surface of Italy by being disengaged in consequence of the action of volcanic fires upon the limestone, and that in the case of the Tuscan lakes the action of those fires extended to the surface where the mountain waters rolled seaward, and enabled it to dissolve caustic calcareous matter. This laid the foundation for Faraday's fame. It was an analysis quite new; it belonged to an entire range of investigation which had been unassailable, and it prepared the way for all the multiform developments of natural matter by chemistry. Native caustic lime had never been known before. Heat from that moment occupied a place in science quite different from any other previous position.

But a notice of Faraday must recognize his minor papers. These contain the germ of much future fruit. The paper on oxide of silver in ammonia shows the probability that a solution of silver of that kind can be employed in the arts for purposes of ornament and utility. His investigations of chlorides contain suggestions far beyond what have been worked, great as they have been, and reveal to man a wealth in nature of which there is little conception. Then of sound produced by flame in tubes there is a singular description. We hear the roar of a flame, but heed it not; Faraday analyzes it, and we perceive a world of sound about us regulated by laws, not only in fire, but in all beside; laws we can define as to the volume and conditions of air and circumstances in which it shall produce sound. He who thus exposes the bounties of Providence, or the methods man should adopt for their utilization, has a claim on the gratitude of the world far surpassing that of any other order of men.

The next important paper was read in 1829, and is now held in great esteem; it is entitled "On the new Compounds of Chlorine and Carbon, &c.," wherein he unveiled the wealth of chemistry employed in combinations by describing form after form of valuable products obtained by scientific distribution and conjunction. He stayed not at any discovery, and on this subject contributed to the common good many brief papers and instructions. In 1820 he published his investigations "On the Alloys of Steel," made in the laboratory of the Royal Institution by many experiments and analyses. He told the world of the infinity of metallic combinations within its grasp; how that carbon gives keenness to the cutler's steel, and that earths and other material could be used to advantage in that manufacture, instancing the Indian steel, about which he discoursed in the most charmingly instructive manner. It is a paper that deserves reproduction for its suggestiveness as much as for its information; it treats of every kind of steel, meteoric iron, &c., and of the union of silver and steel and silver alloys, showing that alloys of the kind he states improve both silver and steel instead of adulterating either. So of copper and of gold.

Combination had a high place in Faraday's mind; he ever turns to it as the resource. It is of necessity the chemist's function, but he exercised it in evolving the unknown, and stating with precision the several elements and their quantities. He discovered the liquidation of gases, a most important factor in a chemist's calculations; and read, in 1825, a fine paper on the "Formation of Ammonia," &c., which was followed by his description of a new compound made from the compressed gas obtained from coal, which, no less interesting than the preceding from a scientific point of view, had besides a great industrial import-

ance. This was a bicarburet of hydrogen in a liquid state, which was found to be a mixture of several compounds endowed with various degrees of volatility, and which could be separated by distillation. Every one knows the advantage, in the production of colours, derived from this by the illustrious Hofmann, when he extracted aniline from it.

As an instance of the practical side of his genius, we must not omit a note on his paper describing pure caoutchouc and the substances it contains when exuded. The information had great value at the time, and indeed is important now, because there are yet several uses to which that material and its adjuncts can be put besides those with which we are familiar. He collected all the known observations made from 1751 to 1825, and corroborated or corrected them by personal test and investigation, thereby augmenting incalculably the general store in the public interest.

Philosophers owe to him quite as great obligations as are apportioned to Dalton, Sir H. Davy, and other distinguished brethren. There appears to be no limit to his power of research and to the perpetual branching out of new theories and unknown laws from every item of discovery. He read a paper on "The Existence of a Limit to Evaporation," in 1826, and instructed Captain Franklin (Sir John) how to make for him scientific observations in the Arctic regions, which, alas! never came to hand. His views were novel, and it is pleasant to notice the modesty of their enunciation, which led him to narrate his facts but deterred him from venturing on a theory until his views had, as he says, the sanction or correction of scientific men. In 1830 he felt himself justified in issuing by an elaborate document his views on "The Limits of Evaporation." On completing his task in 1826 he selected eighteen sets of substances, placed them in respective bottles and stoppered them securely, and so they remained for four years; at the end of which time they were opened and examined and the results published. He shows exactly what substances can or cannot be volatilized, and in conclusion states, "That there is no reason to believe that water or its vapour confers volatility on those substances which, when alone, have their limits of vaporization at temperatures above ordinary occurrence, and that consequently natural evaporation can produce no effects of this kind in the atmosphere." In the interval of these dates he read kindred papers, for instance, "On the Fluidity of Sulphur and Phosphorus;" "On the Nature of the Medicinal Preparation named Chloride of Oxide of Sodium, as shown by Experiments;" "On Anhydrous Crystals of Sulphate of Soda," &c., and delivered also his celebrated Bakerian lecture to the Royal Society, "On the Manufacture of Glass for Optical Purposes," on which Professor A. de la Rive said, "Only those who are called upon to experiment in the domains of physics and chemistry can appreciate the immense service which this treatise has rendered to them, by teaching them a multitude of processes of details so valuable for them to know, and of which a description was previously nowhere to be found. It was necessary that a *savant* who for so many years had been struggling with the difficulties of experimentation, and who had been able to surmount them in so ingenious a manner, should give himself the trouble to describe the means which he had employed so that his experience might be of service to others. Faraday was this *savant*, and his object was completely attained."

Faraday's lectures to children at the Royal Institution in the Christmas holidays did wonders in attracting to science the intelligence of a class, whose circumstances being easy, is too often attracted by pleasure and frivolity. The simplicity of his whole being, and the perfect mastery of the manner of communicating the most abstruse knowledge without abating its substance, won the hearts as well as illuminated the understandings of all who heard, as it will in a less degree all who read those productions. The manufacturers of scientific amusements owe to him many beautiful ideas, and the fund unused in such papers as those on "Optical Deceptions" is still large. The marvellous ingenuity of his operations and the evident delight he felt in every phase are charming. He may be said to have possessed until the end the greeful child-like affection for novelty, combined with a retentive power that enabled him to keep on adding stone to stone of the monument now remaining to us in the record of his career. Of an analogous kind is his brief memoir "On a peculiar Class of Acoustical Figures; or certain Forms assumed by Groups of Particles upon Vibrating Elastic Surfaces." In these he associated himself in sympathy with Wheatstone, although in different lines of thought, as he did on Regelation with Dr. Tyndall, towards whom he stood the intimate friend.

It is now twenty years ago that table-turning excited the intelligent classes and drew from Faraday its death-blow. In a letter to the "Times" (June, 1853) he described his investigation, and administered a stinging rebuke to the public credulity. "I have been greatly startled," he wrote, "by the revelation which this purely physical subject has made of the condition of the public mind. . . I think the system of education that could leave the mental condition of the public body in the state in which this subject has found it, must have been greatly deficient in some very important principle." The particulars of his experiments are in the "Athenæum" of June or July, 1857. It is a narration of facts, with an apology that such a labour should have been necessary for clearing away the delusions of the public.

He delivered another Bakerian lecture in 1857, the subject being, "Experimental Relations of Gold and other Metals to Light;" but he had also given a most valuable lecture before H.R.H. the Prince Consort and the members of the Royal Institution on "Mental Education," a subject in which he was deeply interested and highly competent to elucidate. It is a lecture eminently useful at this time, as it deals with the sceptical tendency of half-educated people, and draws a line between the acceptance of phenomenal knowledge and the acceptance of testimony affecting man's moral and future life; contending for the first, that our powers of learning are all but infinite, and that only a little has yet been acquired; but for the other, that man by reasoning cannot find out God. In these respects, and also in stimulating the popular courage in the search after truth, as at once the greatest honour and the happiest duty of man, he resembled John Locke. The exercise of judgment is insisted on with peculiar force, and the qualifications for the attainment of perfection in that particular are vividly and earnestly set forth.

The most important of Faraday's public services are to be found in the collected papers that have appeared in the "Philosophical Transactions of the Royal Society," the "Edinburgh and London Philosophical Magazine," and the "Proceedings of the British Association," during more than forty years. These form three octavo volumes, and are, in fact, a scientific history of modern electricity, with every species of elucidation and evidence that the most diligent and suggestive inquirer can imagine. They were issued respectively in 1839, 1848, 1855, rising in excellence from the first to the last, which is the most astonishing of all. The fortune of many a man has been made by them, and as for the wealth of light and knowledge exposed to the world it baffles all attempts at analysis or description. The use of gutta-percha for insulation, told of to the world, in 1848, made Atlantic cables possible, and the disclosures on magnetism, electro-magnetism, electricity, form truly almost all we know of those stupendous and multiform sciences. The number of paragraphs is nearly 4,000 and not a line is wasted—all is accurate and scientific matter, detailing fact, thought or experiment. Induction was the most important of his discoveries, and the action of magnetism and electricity upon light the most brilliant. Others had endeavoured to ascertain whether magnetism and electricity exerted any direct influence upon light, and operations upon luminous rays travelling in air or fluids had been made by magnets, currents, and statical electricity; but all had been barren—they were not good enough to be printed. Faraday had his theories and seldom spoke of them, we may might almost say, never. He possessed a strong conviction of the mutual correlation of natural forces, and by perseverance he found out the connection between light and the magnetic and electric forces. He did not experiment on an ordinary ray, but upon one polarized; he did not act on it by a magnet, but by a prism. The results were charmingly interesting, but we have no space in this journal for their exposition. The general phenomenon discovered surprised even the discoverer; he did not expect it, and it has never been explained.

Electricity had in Faraday the most lucid expositor and experimenter, obtaining results which have been seen. He studiously declined committing himself to any theory or dogma concerning the nature of the power, but did not decline to state his progressive thoughts and the results of his efforts. Let him speak for himself: "If electricity exist independently of matter, then I think that the hypothesis of one fluid will not stand against that of two fluids. There are, I think, evidently, what I may call two elements of equal force and acting towards each other. These may conventionally be represented by hydrogen and oxygen, which represent them in the voltaic battery. But these powers may be distinguished only *by direction*, and may be no more separate than the north and south forces in the elements of a magnetic needle. They may be the polar elements of the forces originally placed in the particles of matter; and the description of the current as an axis of power suggests some similar general impression for the forces of quiescent electricity." Again: "Gravity will not turn a corner: its pull is on a right line:" hence his aim and effort to ascertain whether electric action ever takes place in curved lines. This once proved, it follows that the action is carried on *by means of a medium* surrounding the electrified bodies. He electrified by induction an insulated sphere placed completely in the shadow of a body which screened it from direct action. He pictured the lines of electric force bending round the edges of the screen and reuniting on its other side; he proved that distance increased

rather than diminished the charge. His memoirs on induction and conduction given in 1838 did not meet general approval. "Amid much that is entangled and dark there were flashes of wondrous insight and utterances which seem less the product of reasoning than of revelation." It was eighteen years after, Faraday was able to show that the observations of Werner, Siemens, and Latimer Clark on subterraneous and submarine wires were illustrations of the principle he had enunciated in 1838. "A pure vein of philosophy runs through these writings; while his experiments and reasonings on the forms and phenomena of electric discharge are of imperishable importance."[1] We find him returning to his experiments on the source of power in the voltaic pile in 1838 and 1839, which with other kindred investigations continued for three years. His 1834 publication fell unnoticed by the *savants*, because it was a direct attack on the contact theory, then universally accepted. In 1840 he virtually settled the matter. After hanging difficulty after difficulty about the neck of the contact theory, he uses an argument which, had it been understood then, would have spared time and trouble. "The contact theory assumes that a force which is able to overcome powerful resistance, as for instance, that of the conductors, good or bad, through which the current passes, and that again of the electrolytic action, where bodies are decomposed by it, *can arise out* of nothing; that without any change in the acting matter or the consumption of any generating force, a current shall be produced which shall go on for ever against a constant resistance, or only be stopped, as in the voltaic trough, by the ruins its exertion has heaped up in its own course. This would indeed be a *creation of power*, and is like no other force in nature. We have many processes by which the *form* of the power may he so changed that an apparent *conversion* of one into the other takes place. So we can change chemical force into electric current, or the current into chemical force. The beautiful experiments of Siebeck and Peltier show the convertibility of heat and electricity; and others by Oersted and myself show the convertibility of electricity and magnetism. *But in no case, not even in those of the gymnotus and torpedo, is there a pure creation or a production of power without a corresponding exhaustion of something to supply it.*[2]

In recording the facts of this busy life we have to catalogue labours and honours of an extraordinary description. Here, notwithstanding the profound and abstruse investigations, is the man dispensing his knowledge with a free hand. He monopolized nothing, and indeed was not paid for half his work. His advice to the Government, the Admiralty, the Home Office and the War Department had no requital. He declined the professorship of chemistry at the London University, but he accepted a lectureship at Woolwich, and held it twenty years. Then he became scientific adviser to Trinity House at a salary of £200 a year, which he continued to enjoy for thirty years.

Faraday had his ambitions: he desired to add F.R.S. to his name, and would have had it long before it was conferred, but for the jealousy of Sir Humphry Davy, the President of the Royal Society; however, he acquired it in 1824, and from that period to 1867—the time of his death—honours came to him from every quarter. D.C.L. at Oxford, LL.D. at Cambridge, and also from a continental university. Prussia, Italy, France, vied with England in tending her academical distinctions. Twice did the Royal Society give him the Copley medal, and his name is enrolled in the philosophical societies of Cambridge, Paris, Florence, Heidelberg, Philadelphia, Boston, Berlin, St. Petersburg, Palermo, Basle, Munich, Modena, Vienna, Stockholm, Madrid, Bologna, Rome, Haarlem, Turin, Naples, Padua, Venice, Pesth, Breslau, Moscow, Copenhagen, and Rotterdam. The Commissioners to the French Exhibition conferred the Grand Medal of Honour upon him, he was elected one of the eight foreign associates of the French Academy, and although never a university man, was made a senator of London University. He had more than ninety titles, and might have taken the Presidency of the Royal Society had he been so minded. Melbourne placed him on the Civil List for £300 a year in 1835, and in 1858 the Queen placed at his disposal a pleasant dwelling on the Old Green at Hampton Court, where he resided during the remainder of his life, which terminated on Sunday, the 25th August, 1867, as he was seated in his arm-chair. His remains were taken to Highgate Cemetery on the 30th, and elegies were pronounced at all the great English and continental scientific meetings. Soon after his death Dr. Bence Jones and Professor John Tyndall issued their respective memoirs of their friend, and we know few such delightful biographical works in the language. Jones wrote his "Life and Letters, &c.," Tyndall, "Faraday as a Discoverer." The encomiums are remarkably affectionate, recognizing the idea of the combination of simplicity and wisdom in a most unusual degree.

Faraday belonged to a small sect of Christian people called Sandemanians, or originally Glassites; the primitive habits and observances of that body attracted his sympathy; he diligently frequented all their gatherings, at which he often preached extempore sermons. As a scientific man he maintained a firm and decided stand against materialism, although so daring a student of science. At one time somebody dared to issue the slander that he had declared electricity to be life. He never said such a thing, but on the contrary, "Electricity is an implement of life, and nothing more." His moral nature, his grand intellect, revolted against all unbelief, which he regarded with mingled feelings of pity, scorn, and abhorrence. Few of his public miscellaneous efforts gave him such delight upon reflection as the onslaught he made on spiritualism, when, as he said, "he turned the tables on the table-turners." He had a pride of consciousness in reference to all matters whereon he had to give opinions, and humbly boasted that he had never been found to be wrong.

Two years after his death, the government of Mr. Gladstone having refused to carry out the designs Mr. Disraeli had in reference to the public honour of the philosopher, a public meeting took place at the Royal Institution, the Prince of Wales in the chair, and funds were raised solely by public subscription. This project has not yet been realized. The sum of £600 was paid to Mr. John Foley, R.A., as a retainer, and he made a successful model; there are funds providing for its completion with pedestal, and the statue will, in all probability, be placed in the British Museum. The death of Dr. Bence Jones, his friend, and the subsequent demise of Mr. Foley have intervened, causing a delay. But his labour has its own immortality. Those 16,000 notes of his and his published communications are an unexhausted store. His scientific discoveries have enriched hundreds, and thrown a light through the world of a degree that cannot be known. The generation of men in all future time will remember him with grateful hearts, as one of those sublime specimens of a good man that is seldom to be known.

Dumas' "Eloge" has a sentence worthy to terminate this outline paper: "I have never known a man more worthy of being loved, of being admired, of being revered."

W. S. C.

[1] Tyndall, recited by H. Bence Jones.
[2] "Philosophical Transactions Royal Society."

ELECTRIC LIGHT.

II.

IN pursuance of the determination expressed in our September number, page 261, we now continue the subject of illumination by means of electricity, by an account of the machine of M. Gramme, whose invention has recently been brought into notice by its adoption on the ocean steamers of the Compagnie Transatlantique, running from Havre to New York. And in writing of the Gramme machine we are induced to enlarge upon the industrial uses of it—uses to which the inventor has devoted his special attention.

The discovery of inductive magneto-electric currents by Faraday in 1832 opened a new field for study to natural philosophers and inventors. Pixii, a philosophical instrument maker at Paris, constructed the first machine which practically produced induc-

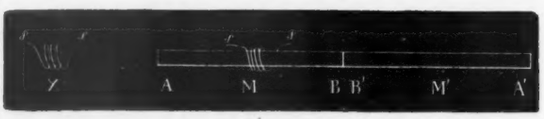


Fig. 2.

tion currents. His apparatus, which was successively improved upon by Saxton, Clarke, Wheatstone, Wilde, Siemens, and Ladd, has rendered immense services to science and even to industry. By an odd fatality Pixii's invention is mostly known by the name of Clarke's machine, although he, of all the physicists mentioned, made the least important improvement in the original machine. Nollet's machine, generally known as the Alliance machine, is also founded on the same principle, being only a peculiar arrangement of a group of Clarke's machines. Gramme's machine is not, like all the preceding ones, a more or less happy modification of Pixii's. It is the first of its kind, as we shall show by the following description.

In order to understand the principle of Gramme's machine,

it is necessary to go back to the simplest experiment of magneto-electric induction that can be made ; but then it must be analyzed more completely than is usually done. Let us take (fig. 2) a magnetic bar one metre in length, and a spiral coil of conducting wire, in reciprocal motion. If the coil is brought near the bar from the distant position X, a current of induction is produced. Such is the chief part of the phenomenon, and there analysis generally stops. But let us go farther,

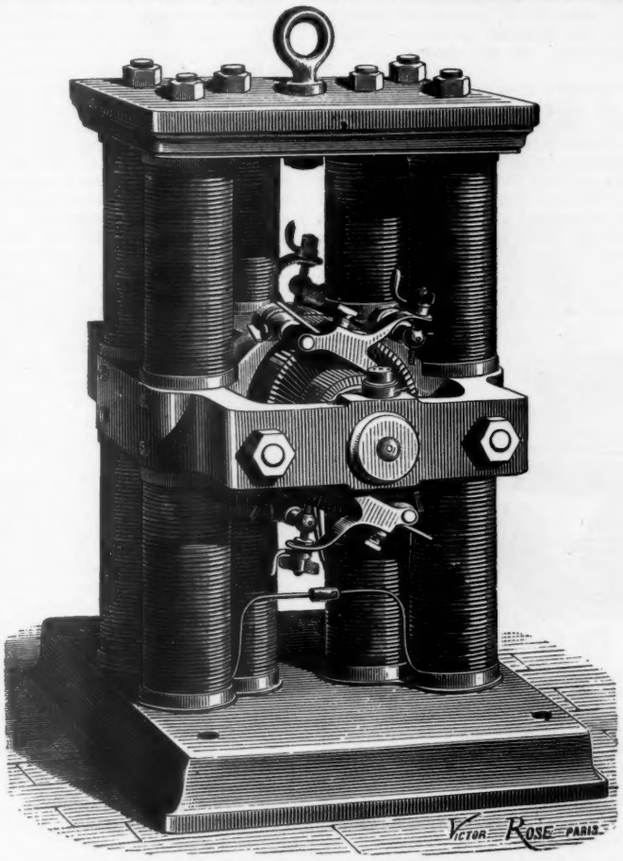


Fig. 1.

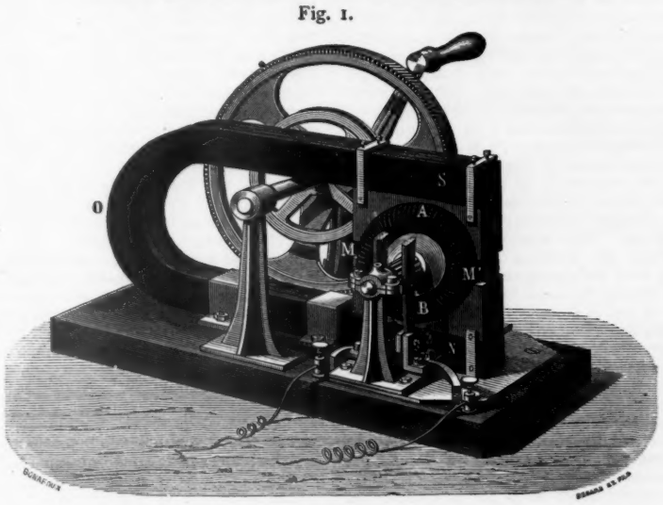


Fig. 4.

and examine closely what goes on, as the bar enters the coil by a series of successive movements of an equal extent, *e.g.* five centimetres. We observe that each of these movements corresponds with a current of induction, and that these currents are in the same direction till the coil reaches the neutral line, that is to say, the middle M of the bar A B ; and that they are in the opposite direction, if the movement is continued in the same direction beyond that point. Thus, in the whole line of the coil over the magnet two distinct periods are observable. During the first half of the movement the currents are direct,

during the latter half they are in the reverse direction. We borrow these particulars from M. Gaugain's memoir in the *Annales de Chimie et de Physique* for March, 1873, a most interesting analysis, indeed, of this phenomenon, in which the magnet is assimilated to a selenoid. If, instead, of operating from the left to the right, the direction is reversed, everything goes on in the same way, but the current takes the opposite drection.

Let us now examine the complex case represented by fig. 2. Two magnets, A B and B^1 A^1, are placed end to end, in contact by homonymous poles B, B^1. The whole appears like a single magnet with a consistent point in the middle. If the helix be set in motion in accordance with this system, it clearly appears from what precedes that this helix conducts a positive current during the first quarter of the movement (between A and M), a negative current in the second quarter (from M to B), another negative current in the third quarter, from B^1 to M^1, and finally a positive current for the last quarter (from M^1 to A^1). Thus the current changes its direction at the neutral points. It will be seen that this most simple experiment gives the clue to the direction of the currents in M. Gramme's machine.

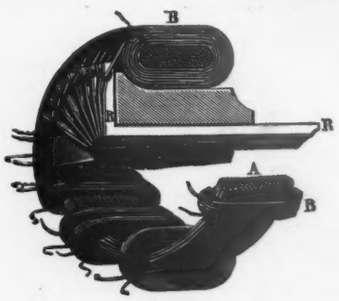


Fig. 3.

The essential organ in Gramme's machine is the ring represented in fig. 3, which turns about its centre between the poles of a magnet. This ring is an electro-magnet of a particular form. It may be imagined as formed by a straight electro-magnet bent into a circle and welded together at the ends, iron to iron and wire to wire. We know that in certain straight electro-magnets, especially those with powerful induction coils, the wire is wound on distinct bobbins, placed one by the side of the other in a chain, *i.e.*, in tension. This is also the way in which the wire is distributed over Gramme's ring. Fig. 3 shows these different wire bobbins, which are the elements of this source of electricity, as the voltaic couples are the elements of a voltaic battery. In order to make the construction of this essential organ more intelligible, we represent it complete in one portion only; in another portion the bobbins are only shown one out of two; in another portion, again, the iron ring is left uncovered and also cut. The soft iron ring is magnetized by the influence of the magnet, N S (fig. 4), and magnetism is to be found distributed on it in the following manner. At B and A are the poles, whilst at the other points at right angles M M^1 there are neutral points. During the movement of the ring this distribution does not change, or, at least, is invariable in position, from the very reason that it changes instantaneously in soft iron, which has no coercive force. Thus everything proceeds as if the circular iron on which the bobbins are mounted were stationary, and as if the wire helices alone were moving on a magnetized bar. The ring may be considered as being composed of two magnets, B A and A B, united at their poles of the same term. If one bobbin is observed during its movement through a complete circle, it will be seen by reference to fig. 2 and the explanations we have given that the current developed maintains the same direction during the whole time it proceeds from A to M. The direction is reverse during the second period between M and B, remains so during the period of B M^1, and changes again at M^1 into a direct current from M^1 to A^1.

For the better understanding of the direction of the current from B to M^1 being the same as from M to A, the simplest way is to suppose that the current from A to M^1 is contrary in direction to that from B to M. This is easily seen by referring to the principle of the machine, and is tantamount to saying that (fig. 2) if the coil goes first from M to A, and then from B B^1 to M^1, the two currents thus produced are contrary in direction, which cannot be a matter of doubt to anybody.

In other words, the current which arises in a bobbin keeps the same direction from one neutral point to the other; when it is direct above that line it is indirect below. The line M M^1 may be called the line of distribution (*ligne de partage*); it is evidently perpendicular to the line of poles of the exciting magnet N S of the machine, whereas the line of distribution in Clarke's machine coincides with the pole line of the magnet. This shows in what manner Gramme's machine differs from the former magneto-electric machines.

From this we see that, supposing the ring to be composed of 60 bobbins, the 30 bobbins, which at a given moment are in the upper half-circle, are all simultaneously traversed by positive currents which successively cumulate their tension, whilst the 30 bobbins in the lower half are likewise the channels for negative currents, superadding their tension. The total of the current above is equal to that below, and the machine in its entirety is comparable to a system of two batteries of 30 elements each, associated in opposition. Now, in order to utilize the arrangement, the two extremities of a circuit need only be connected in communication with the common poles of the two batteries; the currents of the two batteries then cease to be in opposition, and associate in quantity. In the same manner, M. Gramme collects the currents developed in the ring of his machine. He establishes collectors on the line of neutral points. These collectors are formed of copper points, which rub on the series of radiating pieces R (fig. 3), which have a metallic connection with the conducting wires of the bobbins. This being a thoroughly novel arrangement, it behoves us to clearly explain its details and working. Fig. 3 shows the different bobbins or elements of the ring, and the radiating pieces R, insulated from each other, and connected each to the emerging end of one bobbin and the entering end of the following bobbin. Thus it will be understood that the currents are collected by the pieces R as they would be at the junction between the one bobbin and the other. The pieces R are bent at a right angle, and their second portion, parallel to the axis, is located inside the coil and protruding from it. On the complete drawing (fig. 4) may be seen the extremities of the pieces R brought together in a cylinder of a small diameter, but in every case insulated by the interposition of silk ribbons, or any other non-conducting matter. This figure also shows the brushes sweeping the pieces R in a plane perpendicular to the polar line, that is to say, at the medium or neutral points M M^1.

On referring to what has been said about the principle of the machine, it is easy to understand that it supplies continuous currents, and that the direction of these currents will change with that of the rotation.

The continuity of the current evidently results from the motion producing electricity being continuous, and the current never being broken, since the rubbers or brushes begin to touch one of the pieces R before leaving the preceding one, and their flexible and multiple nature causes them to touch always by some of their parts, if not in their entire width. It is easily seen that the intensity must increase with the speed of rotation; experiments show that the electro-motive force measured in opposition is proportionate to the speed. This observation has been verified several times in France and England, and especially by the inventor himself, by means of a small steam motor heated by gas, which worked with great regularity. *A priori* it would seem as if the resistance ought to remain constant; but it is soon ascertained that the intensity is not proportionate to the speed of an invariable circuit, whence we are led to conclude that the resistance of the machine is not constant. This important point has been clearly established for the first time by Mr. Robert Sabine, who, it is to be hoped, will publish the particulars of his experiments. We ought, however, to state at once that this increase of resistance is but a slightly marked one; so that it is quite admissible to state that a machine that with 100 revolutions per minute gives a current equivalent to that of one Bunsen element of small dimensions, with a double speed gives a current equivalent to two Bunsen elements of a slightly larger dimension; with a quadruple speed a current of four still larger elements of Bunsen's, and so forth. It is certain that this increase of the electro-motive power cannot be indefinite, and that there is a limit to it; but as with speeds of 3,000 revolutions per minute the proportionality of which we have spoken yet exists, we may rest assured that the limit is yet very far off, and corresponds with a speed which it is next to impossible to attain in practice. In short, M. Gramme's machine produces continuous currents like a battery—constant currents if motion is uniform, currents variable at will within very wide limits, according to the speed of the motion. According to the intended use, the inventor modifies his machine, so as to obtain effects of tension or quantity by coiling on the ring either fine or coarse wire. It seems indubitable that with an equal speed of the ring, the tension will be proportionate to the number of coils of wire; but the interior resistance grows at the same rate, and in most cases the best results are obtained by using stout wire. It is obvious, however, that if the outside circuit has a very great resistance,

as in telegraphy, it will be more convenient to use fine wire. Gramme's machine may be considered as an element of a battery, and therefore be associated with others of the same kind, similar either in quantity, or in tension, and thus obtain effects which may be calculated beforehand.

Those who have watched the improvements in magneto-electric machines for the last fifteen years are aware that one of the main improvements of the English machines is founded on this sole important point :—the existing magnets of Pixii, Saxton, Clarke have been superseded by far more powerful electro-magnets, excited by the action of the machine. We need not mention that this substitution of electro-magnets for ordinary magnets is also applicable to Gramme's machine. It has been carried out; and it is with machines of that kind we obtain the industrial results of which we shall eventually speak. For small machines, the late discovery by M. Jamin of processes for obtaining magnets of an extraordinary power, and at a reasonable price, considerably reduces the importance of the preceding combination. For manufacturing machines, however, the use of electro-magnets becomes almost an absolute necessity. One would think that the magnetism induced in the electro-magnets would be attended with a considerable expenditure of electricity and power. We have expressed this opinion *viva voce*, and in print; but M. Gramme has shown how the difficulty could be met. This requires some explanation. When an electro-magnet is placed in the circuit of a Gramme's machine, the effect of

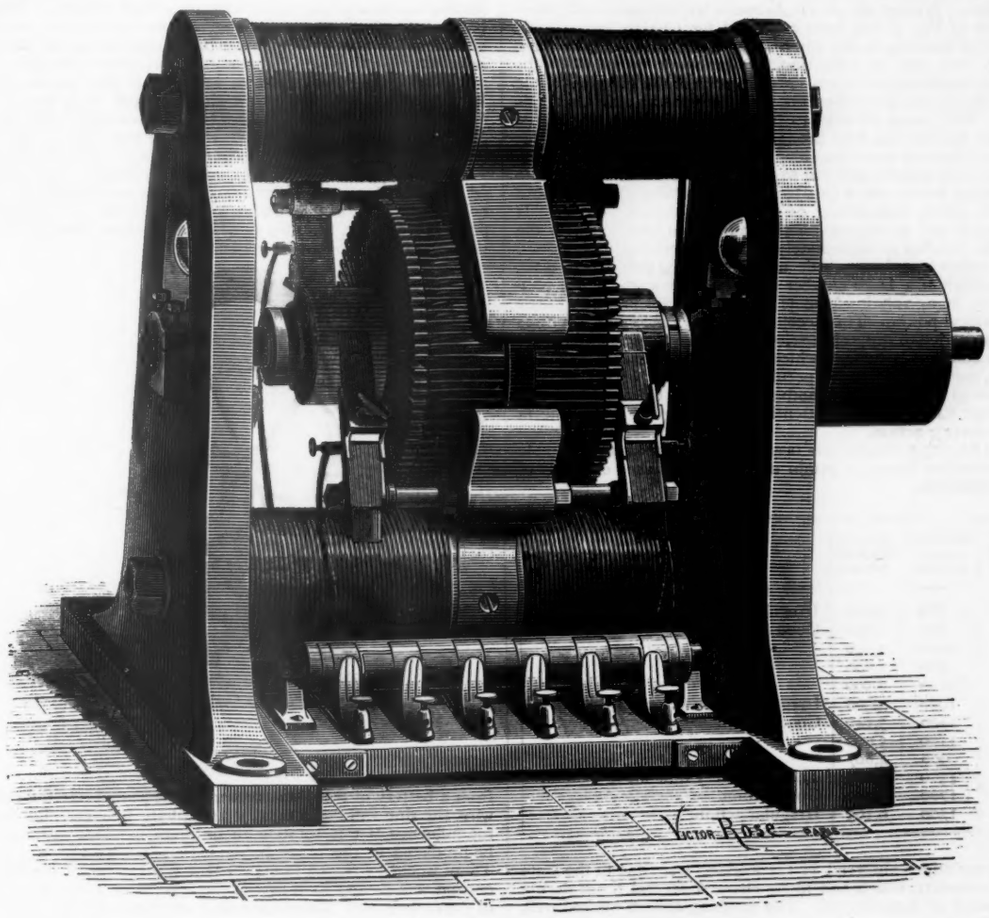


Fig. 5.

the current is, in the first instance, to magnetize it, and then to maintain its magnetization. There is no doubt but the generation of magnetism during the first almost instantaneous period corresponds to a certain expenditure of electricity and power. But what is it that takes place during the second period? Reflection and experiments show that there is still an expenditure of electricity, and hence of mechanical force; but M. Gramme imagines, not without reason, that the magnetic equilibrium having once been obtained, its maintenance might require no more force than that necessary for keeping a spring bent, or to support a weight at a height to which it has been raised. Hence he inferred that nearly all the expenditure was simply occupied in the passage of the current through the wire, and that it would be about the same if the wire, instead of being rolled on bobbins round iron cores, was simply carried in a straight line. This induced him to place in a single circuit the moveable ring, the exciting electro-magnet, and the electric receptor (viz., the galvano-plastic bath, the electric lamp, &c). By this arrangement it becomes useless to have two distinct rings, one for exciting the electro-magnets, the other for furnishing the available electricity. One ring is sufficient. The wire placed on the exciting electro-magnet adds a resistance in the circuit, and thus diminishes the intensity of the current in an inevitable manner, but it is diminished less as the wire is shorter and stouter; and for this reason, M. Gramme has increased, as much as could be done practically, the section of the conductors placed on the electro-magnets. Thus he employs in certain machines, not wire, but sheets of copper as wide as the electro-magnet is long, and which are coiled upon themselves in a spiral form four or five times. Hence, it may be taken for granted that the force necessary for magnetizing the exciting electro-magnets of his machines is all but *nil*.

The idea of coupling in tension two or more Gramme machines occurred naturally, and we have explained it above. But our inventor went still further in dividing each machine, or rather each ring, in the following manner :—We have stated that the 60

bobbins or elements composing a ring are connected with radiating pieces, from which the current is collected by means of the rubbing brushes. M. Gramme bethought himself of putting on the right side the entrance of the 30 odd bobbins, and on the left side the entrance of the 30 even bobbins, thus alternating with each other. Fig. 5 shows the arrangement clearly. Thus we have two of Gramme's rings in one, one bound within the other, the sum total of the electricity produced by the machine being divided into two parts, which are collected by two sets of rubbers or brushes on the right and left sides of the ring. The advantages of this arrangement are very great, whether applied to ordinary magnet or electro-magnetic machines. It allows of coupling the two halves of the machine, either for tension or for quantity, and thus the most diversified effects may be obtained from the same machine. A most simple commutator (represented in the foreground of Fig. 5) has been contrived for passing immediately from one coupling to the other. There are reasons for thinking that a ring and its collecting rubbers work better when the electric tension is twice less, and that each of the two parts of the twin ring is in a better working condition than an ordinary single ring. Still, much remains to be settled on this point, and the *dernier mot* has not been pronounced yet.

The Gramme machine, like all the other magneto-electric machines, is mainly intended to transform mechanical power into electricity, but it also is capable of transforming electricity into motive power, thus acting as an electro-magnetic engine. It suffices to put an electric source into communication with the metallic brushes to immediately set the central ring in motion.

As before stated, very little motive power is required to place in equilibrium a large number of voltaic elements; hence reciprocally many voltaic elements are required for producing little mechanical power. This accounts for the failures of inventors who have tried to apply electricity as a motive power. A machine with a continuous current, which has neither connecting rod nor crank, nor dead points, is peculiarly suited for experiments of converting electricity into motive power. M. Gramme for some time past has devoted his attention to finding the useful effects of his reverse action.

The following results have been obtained by means of a simple demonstration having a Jamin magnet and Bunsen elements of 20 centimetres:

Number of elements.	Number of turns of the ring.	Force in kilogram-metres.	Observations.
2	760	0,320	Irregular action.
3	810	1,020	Good action.
4	1000	1,600	—
„	900	1,800	—
5	1100	2,500	—
6	1000	3,360	Irregular action
7	1100	3,140	Good action.
8	1100	5,000	—
„	900	4,807	—
9	1500	5,115	The check very difficult to balance.
10	1700	5,250	Good action.
„	1300	6,165	Irregular action.

The variations observed in the working were due to the state of the elements, which had to be charged several times during the course of experiments. The machine always worked well, with two elements as with 10. A striking experiment of the same species consists in placing two small Gramme machines in the same circuit. One of them being set in motion by hand, it produces a current which passes into the second and causes it to rotate. If the former be stopped and then be set to rotate in the contrary direction, the latter machine also stops suddenly, and then begins to rotate in the opposite direction. This experiment we think is worth the attention of those who take an interest in mechanics; for it affords in a singularly striking manner a reversible mechanical system. The idea of reversibility, introduced into science by Sadi Carnot, is historically speaking, and at its starting point, what is called "the mechanical theory of heat"—a theory which now comprises the entire physical and mechanical sciences. This idea of reversibility is habitually represented in such an abstract form that very few believe in it and make it a subject of study, whilst in reality it is very simple and plain. We hold that the experiments on the double inverse working of Gramme's machine will help to popularize the idea. This will not be one of the least services rendered by the Gramme machine, for as we may state *en passant* nothing in the present state of science is of greater importance than the mechanical theory of heat.

Let us also mention an easy experiment which is not quite uninteresting. By setting a Gramme machine to rotate, and sending the current into a secondary Planté battery, the latter becomes charged. On stopping the rotary movement without breaking the connection, the secondary current produced by the battery returns to the machine and turns it in the same direction as during the first period. Further on we shall describe a peculiar feature of the electrotyping (galvano-plastic) apparatus, which may be accounted for by a phenomenon of the same kind as that just alluded to.

We know that the induction bobbins invented and examined by Messrs. Masson and Brequet (*Annals de Chimie et de Physique*, 1842), and improved, with the help of M. Ruhmkorff, by the efforts of so many physicists, are apparatus for converting quantitative electricity into electricity of a high tension. Thus a bobbin of ordinary dimensions allows the continuous induction current of two Bunsen elements to be changed into an intermittent induced current, giving off sparks one centimetre in length. We are certainly below the mark in saying that the tension of the latter is one hundred thousand times greater than that of the former. M. Gramme has shown (*Comptes-rendus de l'Acad. des Sciences*, 23 Nov. 1874), that his machine may likewise be used for transforming electricity and imparting a greater tension to it. For that purpose he employs a kind of unsymmetrical twin ring—*i.e.*, the set of even bobbins made of fine wire, whilst the odd bobbins are made of coarse wire. This ring is placed between the poles of a magnet, as at fig. 6. Let us suppose that the current

Fig. 6.

from a battery of two Bunsen elements be passed into the coarse wire, the ring will begin turning as explained above. But under the influence of this rotation an ordinary machine current will be produced in the other bobbins, those wound with fine wire. There would be reason to expect that the tension of the second current was greater than that of the first; such is also the result of the experiment. In an apparatus so arranged, the tensions of the exciting and induced currents are as 1 : 8. Here we are dealing evidently with a transformation of electricity and a change of tension like that produced by induction bobbins; but instead of enormous ratios between the tensions of the two currents, which can only be guessed and not measured, we find tensions in ratios which it is easy to measure, and probably to calculate after the matter shall have been examined more deeply. We may say that the transforming capacity of the induction bobbin is quite different from that of the Gramme machine; but just because the latter does something else than Ruhmkorff's apparatus, it may be hoped that it will give new results and render new services. We shall only allude to one instance; the current of two Bunsen elements being transformed by the system described, will give a tension equal to that of 16 Bunsens, and hence a current equivalent to that of about 30 Daniell elements, and with which telegraphs might be worked to great distances. It is important to remark that not only does Gramme's apparatus allow electricity of low tension being transformed to a higher tension, as stated, but also to effect the reverse—*i.e.* convert the current of the tension of 30 Daniell's into a weak current of about 2 Bunsen's. It is certain that no metamorphosis takes place in these conversions, but rather a loss, more or less; and we may say, paraphrasing

a mechanical truth :—What is lost in tension, is gained in quality, and *vice versâ*.

M. Mascart first pointed out the possibility of employing the Gramme machine for measuring electro-motive power. The proportion of the tension to the speed of rotation having been tested between rather wide limits (one to ten Bunsen), any electro-motive power may be measured by the method of opposition solely by the speed of rotation of the ring when equilibrium has been established. This measurement of speed may be effected in two different ways: either by Deschien's velocimeter, or by means of a chronoscopic diapason. The velocimeter is an extremely handy instrument. It suffices to press it for ten or twelve seconds against an axis or spindle to ascertain the number of revolutions. However, it often happens that the speed cannot strictly be kept up constantly during twenty seconds, and then the use of the diapason becomes necessary for measuring time. The way of operating is as follows: A small disc, whose plane surface is blackened by holding over the flame of a candle, may be mounted on the axis of the ring; a diapason vibrating 100 times per second, and carrying at the end of one of its branches a small style, is held by hand or preferably by a special support. At the precise moment when the galvanometer tells that the two electro-motive powers are equal, the operator presses the style against the disc, and a sinuous trace is thus produced. A short space of time suffices; in fact, a half revolution of the ring, a few hundredths of a second, would be all that was required. The speed of the ring at any given instant is, as it were, registered on the disc. The experiment having been thus conducted, the engine is stopped and a note taken of to what fraction of the circumference the sinuosities

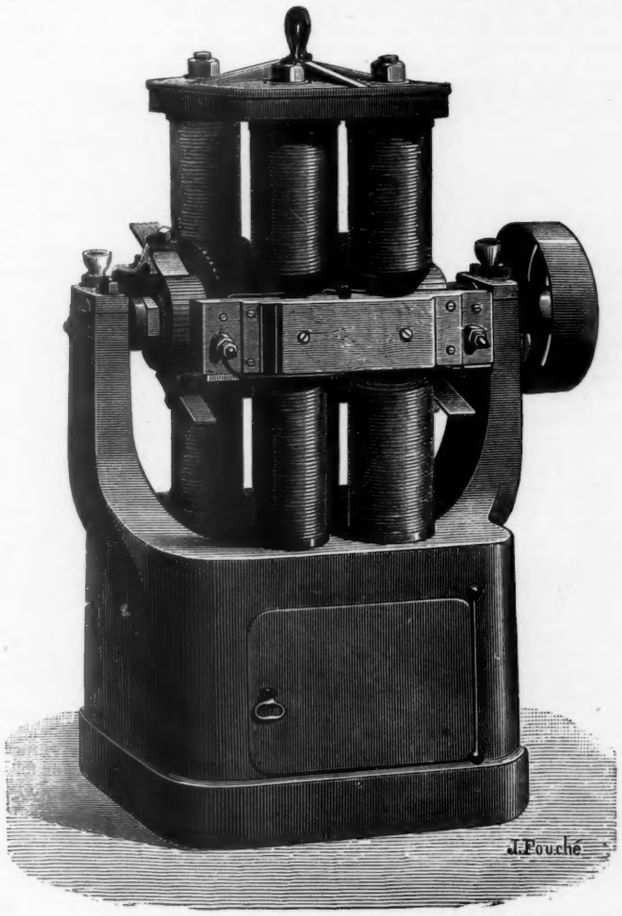


Fig. 7.

traced on the disc correspond. From these data may be deduced the number of hundredths of a second in which the whole revolution of the ring would take place at the speed observed; and the angular speed of the ring in fractions of a second is obtained at the same time. The use of the method of opposition, so satisfactory to mind or logic, is not always easy, and in order to measure an electro-motive power with any precision, we must make use of the thermo-electric battery, which is neither a commodious nor a cheap instrument. The advantage of the Gramme machine in this case results from its electro-motive power being capable of taking any possible value from zero, which is not the case with ordinary batteries, nor even with the thermo-electric batteries as used. We all know that it is very difficult to obtain a strictly constant current with batteries, not even Daniell's, which in this respect is the best known. With Gramme's machine nothing else is needed but to impart a regular speed to it in order that the current produced may be of absolutely even intensity.

There are two prototypes of Jamin's magnetic machine. One of these has been expressly designed for laboratories, &c. This apparatus is suitable for any experiments of natural philosophy, such as electrolysis, exciting electro-magnets, induction bobbins, Ampère or electro-dynamic experiments, &c. It is well known that the trouble in mounting a few elements of the Bunsen battery is often an obstacle in the way of an experiment which in many cases is but to last for a short time. It may be added that the expense for mounting the batteries is by no means trifling, whilst the muscular force of the operator or his helps is the only expense incurred by the use of Gramme's machines. Moreover, there are numerous advantages in the command of a source of electricity which may be varied at will, and from which, by extra exertion or speed, more may be instantaneously obtained than at the normal speed.

The first machine made by Gramme, in 1872, for Messrs. Christofle & Co., Paris, has since been at work to the entire satisfaction of that firm. No repairs were required, and

the whole cost was the expense of lubricating oil for the two brushes of the central shaft. The frame is made of bronze, and rests on a large wooden foundation. Without altering the electrical portion, the inventor constructed, at the end of 1872 and the beginning of 1873, ten more machines, with a cast-iron frame, such as represented in fig. 7, and Messrs. Christofle purchased six of these machines, which are now at work in their factory. These machines weigh 750 kilogrammes (about 1,650 lbs.) each. They measure 1·30 metres in height, and 0·80 metres at their greatest width. Each of them has four electro-magnetic bars and two bobbins. The weight of copper used in their construction is 175 kilogrammes (385 lbs.). They deposit 600 grammes (20 oz.) of silver per hour, requiring for that purpose a force of 75 kilogrammetres (one horse power). Since that time the inventor, by dint of calculation and experiments, has brought out a new class of galvano-plastic machine, which is much superior to the preceding ones. This machine, represented in fig. 8, has only one bobbin instead of two, and two electro-magnetic bars instead of four. Its total weight is 178 kilogrammes (391 lbs.). The copper on the bobbin and the electro-magnetic bars is 47 kilogrammes (104 lbs.). It measures 0·55 metres (42 in.) square by 0·60 metres (48 in.) in height. The deposit is as with the former machine, 600 grammes of silver per hour. Its working is perfect in every respect, as testified recently by Messrs. Christofle and Co. The motive power required is only 50 kilogrammetres, or three-fifths of a horse power. Thus, compared with the 1872 pattern, the 1874 machine presents the following advantages: it occupies one-half the space, weighs less than one-fourth of the weight of the former, the weight of the copper is reduced to one-fourth, and there is a saving of 30 per cent. of motive power. These improvements have been obtained by the suppression of the exciting bobbin by placing the electro-magnet in the very circuit of the current, by a better arrangement of the copper mountings of the bobbins and electro-magnets, and by an increase of speed which has no prejudicial effect on the regularity of the working and the wear of the parts. The mount of the electro-magnets which M. Gramme made of round wire is, in the new machine, made of copper sheet, both for the bobbins and the electro-magnets, covering the entire width of half a bar, so that in reality the mount only is composed of four strips, forming each a single coil. The mounting of the bobbin is made of thick flat wire, sufficiently strong to resist centrifugal force, so as to allow the axis to make 500 turns per minute, whereas in the former machine the speed did not exceed 300 revolutions. No spark is produced at the contact of the metallic brushes and the bundle of conductors soldered to the bobbins. Neither the ring nor the electro-magnets become heated. The brushes are easily adjusted, and may be put out of contact even whilst working. The frame is very firm; the shaft, which has but little to carry, is made of steel; the bearings are of a very small diameter, which reduces friction; the armatures are firmly fixed on the electro-magnetic bars, and embrace nearly the entire circumference of the bobbin. The special arrangement by which the electro-magnet is placed in the circuit, so as to suppress the exciting bobbin, gives rise to a phenomenon of change of pole detrimental to the operation of the machine, but which M. Gramme has counteracted by a simple and most practical combination. When the machines are in motion, and their circuit is closed in the metallic baths, the poles remain the same during the whole operation, but as soon as there is any stoppage from a voluntary or involuntary cause, a secondary current is at once furnished by the bath, as in the experiment with Planté's battery described above. This current, travelling through the wires of the electro-magnets, imparts to them a magnetism contrary to the one with which they were animated before. Thus the remaining magnetism, which would have acted as the starting force if the machine were set in motion without interfering with the conductors, produces an inverse current and an inverse effect; that is to say, taking the case of electro-plating for instance, if a strap happened to slip and fall off the pulley, if the same were put on again and the action continued, the articles in the bath would be *unsilvered*. In order to obviate this grave inconvenience, M. Gramme's contrivance is to cut off the current automatically as soon as the speed of the machine slackens. He thus avoids the secondary currents which alone cause the poles to be changed. When after a stoppage it is desired to go on, nothing is required but to hold a small metallic blade (a so-called current-breaker) near the electro-magnets, so as to re-close the circuit and restore the machine to its normal working. This "breaker," as applied to the new machines, is a small movable piece with a balance-weight bringing the metallic brushes against the electro-magnets; as long as these are magnetized, they keep the "breaker" in contact, but as soon as the speed of the machine slackens, and thereby the attraction of the magnets is diminished, the balance-weight causes the "breaker" to tilt, and the electric communication between the central ring and the electro-magnets is broken. No secondary current can arise at the moment of stoppage, and consequently the poles remain the same. In order to check the advantages obtained by his new galvano-plastic pattern, as compared with the previous one of 1872, M. Gramme altered one of the old machines by applying all the recent improvements to it. This transformation produced the result anticipated, for the silvering was increased to $2 \cdot 100^{k}$ per hour, instead of 600 grammes. Amongst the machines in use for the last two years for depositing metals, we may mention seven at Messrs. Christofle and Co.'s, besides a late order for six of the new pattern by the same firm; one of Messrs. Blanzy and Poure, pen-makers, at Boulogne; one for the University of Pesth; one at Mr. Olsanski's, Warsaw; a most powerful machine capable of depositing 10 kilogrammes (22 lbs.) of silver per hour, for Mr. Wolhill, Hamburg, &c.

The first machine for producing electric light made by M. Gramme fed a regulator of 900 carcel burners. Its total weight was 1,000 kilogrammes (1 ton). It had three movable rings and six electro-magnetic bars. One of the rings excited the electro-magnet, and the other two produced the available current. The copper coiled on the magnets weighed 250 kilogrammes, on the three rings, 75 kilogrammes. The machine stood in 80 centimetres square by $1 \cdot 25^{m}$ in height. The machine which was used for some time for the experiments on the clock tower of Westminster (the Houses of Parliament) became slightly heated when at work, giving off sparks between the metallic brushes and the bundle of conductors on which the current collects. However, this machine, during two years of use, did not give rise to any serious complaint. M. Gramme at once tried to do away with the sparks and the heating, and as the intensity of the light required by various governments did not exceed 250 burners, he was enabled to reduce the dimensions of his first machine.

The machine fig. 1 represents this first transformation. It still had six electro-magnets; but instead of being arranged in two straight lines the bars are set in a triangle. Two rings allow the total current to be sent either to both magnets or one of them, or utilized in producing two separate lights. This machine weighs 700 kilogrammes. Its height is 90 centimetres, and width 65 centimetres. The copper coiled on the bars weighs 180 kilogrammes, and the two rings carry 40 kilogrammes of the same metal. It produces regularly a light of 500 burners, which at high speed can be raised to twice that illuminating power. It is not subject to heating nor scintillation. When the current is sent into two regulators, each of them gives 150 carcel burners. The last type is represented on Fig. 5; it constitutes, as will be seen, a great progress on all that has been done hitherto towards solving the problem of electric light.

The form is the same as that of the galvano-plastic machine, consisting mainly of a cast-iron frame with two standards or ends, two electro-magnets, and one single movable central ring.

This machine weighs 183 kilogrammes. Only 47 kilogrammes of copper were required for its ring and the same for the mount of the electro-magnets. It stands in 55 centimetres square, and 60 centimetres height. Its normal power is 200 burners, but can be raised considerably. The following table gives the result of six series of experiments:—

Number of Turns.	Number of Burners.	Observations.
650	77	No heat nor sparks.
850	125	" "
880	150	" "
900	200	" "
935	250	Slight heat, no sparks.
1025	200	Heat and sparks.

This is not the place for discussing the Alliance Machine, which has always given excellent results for illuminating light-houses. Still, in order to demonstrate the improvement realized by M. Gramme, we may mention that an old machine of that description supplying 200 burners weighed about 2000 kilogs., and required a space of 1·70 m. by 1·30 m., and 1·50 m. in height. The new machine we have described thus weighs one-twelfth the weight, and squares in one-seventh, whilst cubing one-eighteenth of the space occupied by the said machine. It must not be forgotten that amongst the improvements introduced by M. Gramme in his new lighting machines, there is the central ring, which has a double collector of currents, or, as we said above, is separated in twain. By this advantageous arrangement, scintillation is done away with, and the number of bobbins may be increased

to a large extent. This construction also permits of coupling the two halves of the machine both for tension and quantity, and lastly, of producing two distinct lights. This division of electric light is no doubt one of the most interesting problems of this science. That which limits the use of this source of light is not the cost, inferior to any other; but its glaring brilliancy is concentrated in one point; and whilst throwing a dazzling light in one direction, it leaves in darkness those portions which are in the geometrical shadow of the objects illuminated. Thus it is that lights much less intense, but divided and scattered, are almost always preferable in practice. Hence, the splitting or division of the ring must be considered a most important improvement for the purpose of lighting railway stations, workshops, court-yards, public halls, &c. A single electric light generally proves insufficient, whilst two of them placed in opposite positions will in many cases solve the problem, the geometrical shadows projected by the first light being illuminated by the second. But we may go further, and there is no obstacle in the way of having four lights with two machines. Nor is this all. M. Gramme constructs machines of 50 and 100 candles, which may be utilized in many cases, and afford the means of having several lights for one locality. Thus, the new foundry of Messrs. Heilmann-Ducommun & Steinlen at Mulhouse will be lit by four lamps of fifty carcel burners each. Already for some time past M. Gramme's workshop is lit every night with one single lamp; and this practical experiment deserves to be noticed here. The atelier is in one room, or a single light would not suffice. The light is placed at some height—so as not to

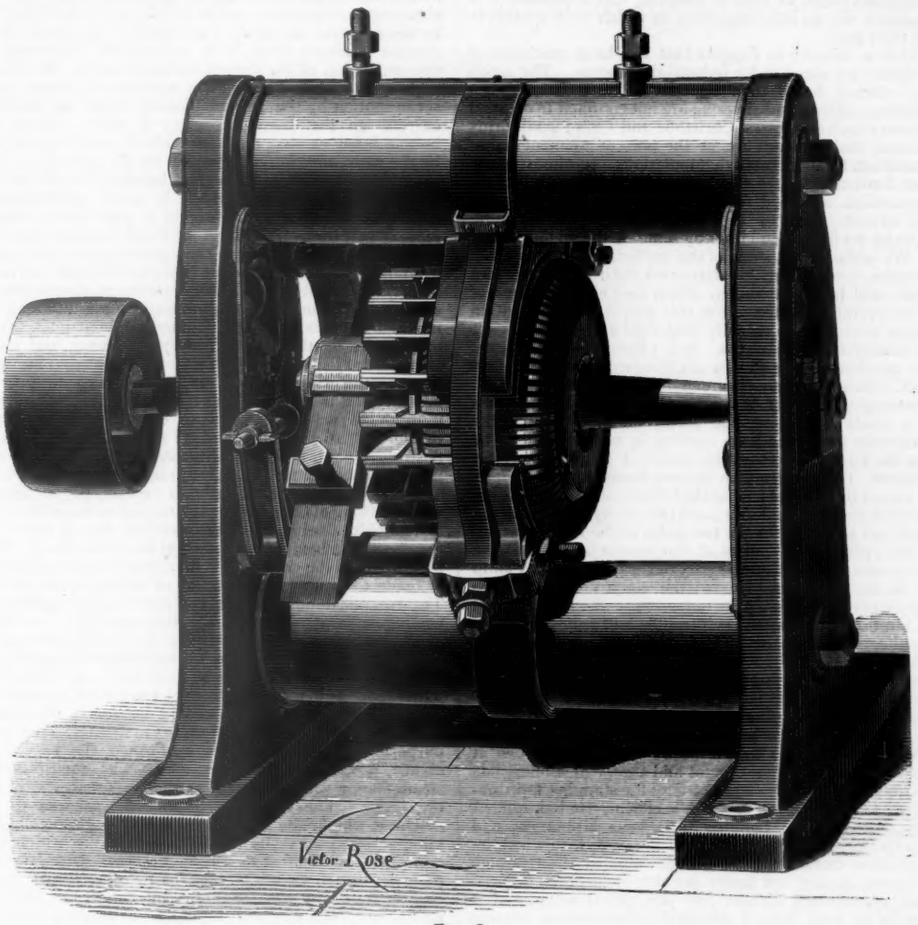


Fig. 8.

meet the eye of the workman—in a diffusing globe, in such manner that the light is not obtained from a luminous point or focus, but from a large snow-white globe. The shadows are thus softened down very much, and the decided opposition of shadow and light, so objectionable in the ordinary electric lighting apparatus, entirely disappears. The ceiling and walls, although not of a pure white, as could hardly be expected in a workshop, are of a light grey shade, such as walls will be after being whitewashed every six or eight months. This, of course, is a very favourable circumstance, but which may in most cases be made sure of. We need not say that walls blackened by smoke or otherwise would never answer the purpose. *Summa summarum*, since the atelier was not built expressly for M. Gramme, but is like the generality of workshops, rented, we may take it for granted that in many cases one lamp will do, and that the operatives work under it as comfortably as in broad daylight, owing to the diffusion procured by a special globe. Very little shall we say about the electric luminary as applied to lighthouses. This application, in fact, has been the most successful of any to this day; and an experience of eleven years at the lighthouse of La Hevè, without one night's interruption, shows beyond doubt that before long all the great beacons will be worked with electric lights and machines. The economy in the first cost is so very considerable as to allow many dangerous coasts to be provided with the warning signal. We would further observe that M. Gramme's "splitting" method may also be utilized for lighthouses. There is nothing to prevent having two lights—one above the other—on the same tower, which would be a most striking, distinctive signal to warn the navigator strayed by bad weather into dangerous waters. These double lighthouses might, moreover, be diversified by two different colours, or the eclipse or intermittence of one of them. As to its use on board of ships, the Gramme machine presents a decided progress. Not only, *cæteris paribus*, is it less bulky and heavy than its predecessors, but its parts are more firmly connected together; so that the vibrations of a steamer, for instance, cannot affect

the true position of the working parts. The yacht "Livadia," belonging to the Emperor of Russia, was fitted with a Gramme machine in August, 1874, and there is every reason to believe that this example will be imitated. The day will come when all large steamers will be powerfully lighted, and collisions will be less frequent; for, with a few exceptions, it is these powerful steamers that run down ships of a lighter tonnage or sailing vessels. Besides, why should not the large sailing vessels, with a numerous crew, be provided with a Gramme machine, to be driven by a small engine, to be lighted during hazy nights? A much greater amount of safety would thus be secured at a very slight expense, since the machine need not be used in daytime or during clear nights. Taking into consideration the interest which navigators, passengers, shipowners, and insurance companies ought to have in adopting this appliance, it is to be wondered why so little readiness, or rather such apathy, is shown on their part.

It would be a mistake to suppose that the large machines of this description are alone fit for industrial purposes. The small ones have already found their application in various trades. Electro-plating, gilding, and silvering are not confined to colossal establishments such as Messrs. Christofle and Co.'s; small firms in Switzerland and the Jura are at the present moment using weaker machines for their small manipulations. In almost every case where Bunsen or Grove elements or batteries with bichromate of potassium are used for manufacturing purposes it will be found advantageous to supersede them by a Gramme machine, to be set in motion either by hand or the engine of the factory. We will mention some of the applications of this kind. Electro-sorters, or apparatus for separating the iron or the oxides of magnetic iron from the ore in which they are found, are of great use to several industries. For this purpose M. Deleuil, in a very happy manner, has recently contrived an electro-magnet with very extensive polar surfaces. It is proposed to substitute Gramme's machine to the five or six Bunsen elements at first used by M. Deleuil, and success can hardly be doubtful. M. Villiers, managing director of the St. Etienne coal mines, has invented a mode of closing the safety lamp, by which the miner is virtually prevented from opening it, which can only be effected in the lamp department by means of a rather powerful electro-magnet. The construction of these lamps is most simple. They are closed by a bolt placed at the bottom of a double cavity in the lowest portion of the lamp; and this cavity is so arranged that the bolt can be drawn by the two poles of the magnet which the lamp-man alone has control of, but cannot be moved by a knife or any other attempt on the part of the miner. This lamp had been in use for several years; the electro-magnets were excited by means of bichromate of potassium and sulphuric acid batteries, but they gave rise to such trouble and annoyance that M. Chanselle, the company's chief engineer, on hearing of Gramme's machine, thought of trying it. The machine is mounted on a table, with a fly-wheel and treadle underneath it. The two poles of the electro-magnet stand forward in front of the table. The lamp-man, seated before the machine, operates it like a foot-lathe, whilst his hands are free to manipulate the lamps. Six or seven machines are in use at St. Etienne and two at Montceau-les-Mines (Messrs. Chagot and Co.). M. Lufléry has had the happy thought of using electricity for stopping knitting-frames when a thread breaks or a needle is bent. He has applied it to forty frames at the Langlée Mills, near Montargis, and employs a Gramme machine instead of the acid, with which he had the greatest trouble. During eight months the Gramme machine turned during ten hours per day at the rate of 1,500 revolutions per minute, without any perceptible wear; and it would yet be at work but for personal circumstances beyond our province. Instead of four men for tenting or minding forty frames, they now have at Langlée one minder to each frame. The numerous hosiery manufacturers are now about introducing the electrical stop-motion, by which such saving can be realized. The reader will find more detailed particulars on this subject in No. 1 of the *Revue Industrielle*, February, 1874. An engineer has taken up the old idea of increasing the catching of locomotive wheels to rails by magnetic attraction, and used Gramme's machines for producing the exciting current. It appears that his experiments have been quite successful. We need not point out the importance of this application with reference to mountain railways, and its influence on the cost price of future railways. We feel bound to say a few words about two experiments, which have not yet led to any practical result, but which, nevertheless, are very important. A Gramme machine and a secondary Planté battery may be combined when only an intermittent current is required at regular or even irregular periods. Let us suppose, for instance, that on board ship or a lighthouse intermittent flashes of five seconds be wanted every minute; these can be obtained by a battery of twenty secondary couples which have to be re-charged during the remaining fifty-five seconds. It is obvious, then, that with a machine of one-twelfth the power necessary for a constant light flashes of five seconds per minute may be obtained. The Gramme machine and its motor may thus be reduced to very small dimensions, with a trifling consumption of fuel. Hitherto (in France, at least) no telegraphic apparatus, properly so called, has been worked by means of a Gramme machine. However, the great inconvenience caused by the batteries, which have to be carried, will probably induce armies to use the continuous current of the magneto-electric machine, which can be worked by a handle or a treadle. We should say that an ordinary sewing-machine table, carrying one of Gramme's apparatus specially constructed *ad hoc*, would answer all the purposes of ordinary telegraphs. The application to medicine is still easier, and want of time alone has prevented its having been introduced, for Gramme's machine, with a few alterations, suits every case in which electricity is recommended by the doctors. It effects cauterization by means of an incandescent platinum wire; it is suitable for producing chemical decomposition of the tissues, as employed in the resolution of certain tumours; it supplies a continuous current, and can be set in motion by the patient himself, whilst he discharges the current on the diseased organ; it allows of the induction bobbin being excited, and is capable of producing its own shocks by the mere addition of a breaker on the axis of the ring. The extra current resulting from the "breaking" in this machine has a considerable tension, which is easily understood, as the machine represents a wire wound a good many times round a piece of soft iron. Dr. Moret, of Paris, who has given his attention to electricity applied to therapeutics, says that, after trying a small Gramme machine, he finds that it fulfils all the requirements, and would become, when introduced, the universal medico-electrical machine. Fig. 6 represents at one-fifth scale a medical machine constructed with a foliated Jamin magnet. The weight of the wire on the ring is only 75 grammes, and its diameter is $0{\cdot}0002^{m}$. Weight of magnet $1{\cdot}870^{k}$. The proportion between the wheel on the handle-shaft, and the pinion on the central shaft is 1:15. With a speed of 32 revolutions per minute it produces an equal result to 8 Daniell elements; with 64 revolutions, 16 elements; and 32 elements with 128 revolutions. A strong clock-work would drive it. Fig. 9 represents a common magnet machine, for the lecture-room and small work.

The reader will remember what we said, p. 360, about the reverse working of Gramme's machine, and an experiment by which, two machines being in the same circuit, one of them is made to turn by the influence of the current from the other. This experiment realizes the conveyance to a distance of mechanical force, or better to say, the transmission of motive power at a distance. The two machines may be compared to two pulleys, the connecting wire representing the belt or strap. As the driving pulley turns forward, stops, turns backward, changes speed, so does the driven pulley, and so it is with the two Gramme machines. Hence a machine need only be fixed near any source of motive power, and set in motion, to convey the electric current by a cable to a second machine, which may be located at any distance from the driving machine, and is thus set in motion for any practicable purpose. The inventor has performed the following experiment. A magneto-electric machine was set in motion by a steam-engine with a power of 75 kilogrammetres as measured by the brake. The electricity produced was sent to a second machine, which, the power produced being gauged, showed 39 kilogrammetres by the same Prony's brake, which was rather more than one-half of the original power. Since the electricity passed through two machines, or in other words, there was a double transformation of power into electricity and electricity into power, each machine, although not made expressly for that purpose, produced in reality more than 70 per cent. of effective power. This idea wants maturing, but it seems impossible that it should not cause a great sensation in the engineering world. It supplies the means of utilizing afar the force from waterfalls, so frequent in mountains, as well as the tidal currents, &c. We will give an instance. The Seine is now canalized in its full length; a series of weirs established in the navigable portion puts it entirely under the control of the engineers, who regulate it as may be required. At each of these weirs there is a difference of level more or less great and a consequent loss of power, which might be collected by turbines and distributed to the neighbouring towns and manufacturing districts. At the weir of Port à l'Anglais, above Paris, there is a daily loss representing a force of 3,000 h. p. The weir is only 1,000 or 1,500 metres from the fortifications; and there is no reason why, some time hence, a large Gramme machine, or a set of them, should not be used for taking the power collected by the turbines and transmitting to Paris a suitable number of currents to turn another set of Gramme machines for the use of the various workshops in Paris. Supposing even that out of 3,000 h. p. to be obtained at Port à l'Anglais two-thirds be wasted, would it not

still be a grand result to supply the manufacturers at Paris with a daily power of 1,000 horses? We do not think of asserting that the distance to which the power has to be "wired" is immaterial and of no influence on the economical co-efficient of this combination; the contrary is quite certain. Whenever a current is transmitted, the conductor opposes a certain resistance and becomes heated to a certain extent. This heating may be imperceptible, especially if the conductor is exposed to the air and gives off its heat by radiation from a large surface. Still, the fact of this generation of continual heat is incontestable, and all the heat imparted to the cable, whether lost or kept by it, is taken from the mechanical power of the driving machine. Besides, practically speaking, a cable can never be completely insulated, and on its whole length loses a certain portion of its electricity, in the same manner as gas is lost by escapes in the pipes, as witnessed by the black soil which surrounds underground piping. If the cable were kept in the air, and in dry air, the loss would be very small. It is considerable at the supports, whatever the supports be made of, if the conductor is exposed to the air on poles, but the waste is greatly reduced by covering it with insulating matter.

Some unforeseen difficulties may arise, but we do not hesitate to say that this new mechanical combination will cause an industrial and economical revolution.

A note by M. L. Denayrouze, on a new electric lamp, invented by M. P. Jabloschkoff, was communicated to the French Academy recently, and reported as follows in the *Comptes Rendus* of October 30, 1876:—

"I have the honour to bring before the notice of the Academy the result of studies pursued in my workshops by M. Paul Jabloschkoff, formerly a Russian engineer officer, on the question of electric illumination.

"The discovery of M. Jabloschkoff involves, first, the absolute suppression of all the ordinary mechanism employed in ordinary electric lamps. The new source of light is composed of two

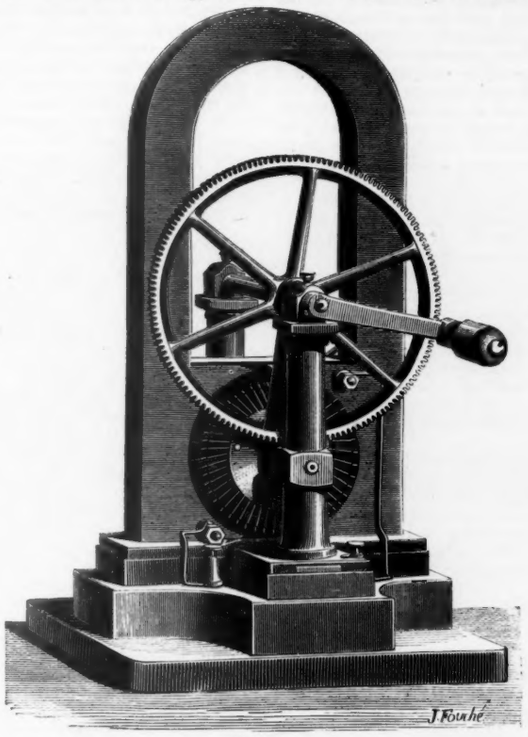


Fig. 9.

parallel fixed carbons at a small distance from one another, and separated by an insulated substance susceptible of consumption at the same time as the carbons. When the current commences to circulate, the voltaic arc springs to the two free extremities of the two carbons. The nearest coating of the insulator melts, is volatilized, and slowly lays bare the double stick of carbon, in the same manner as the wax of a candle progressively uncovers its one wick in proportion as the combustion is spread downwards.

"The idea in question, that appears at the outset but a simplification, truly involves important consequences in the production of electric light by the suppression of the regulators.

"The heat from the combustion of the carbons lost in the air with the regulators, is utilized with the light for the fusion and volatilization of the insulated substance. The composition of this can be infinitely varied, because the greater part of the earthy substances may be employed. Matters reputed the most infusible are volatilized when they are introduced into the heart of the voltaic arc, as we can do, thanks to the disposition adopted for the electric candle. We indifferently employ for the insulated substances, sand, glass, mortar, lac, &c. Our most simple mixture, provisionally adopted as the least costly, is composed of sand and pounded glass. The light resulting from the incandescence of this substance in the voltaic arc produces effects analogous to those of the Drummond light. We do not pretend to have obtained the best mixture at the first trial, but it has already given us, with equal electric force, double the light of a regulator.

"Finally, we have succeeded in graduating the electric light produced by a single source of current. With a single Gramme machine, of the ordinary type of the Bréguet factory, we obtain a light of three candles at once."

Professor W. A. Anthony, in the course of a recent series of experiments in America with an electro-magnetic machine of the Gramme pattern, made the following interesting observations:—"The electric machine was driven by a five-horse Brayton petroleum oil engine. The engine consumed a little over six and a half pounds of crude petroleum per hour. The lamp used in the engine, by which the explosive mixture is fired, had a one-inch flat wick, and consumed 29·8 grammes (459 grains) of oil per hour. The power resulting from the motion of the engine, when applied to the electric machine, produced a stream of electricity or electric light, having an illuminating power equal to that of 234 of the lamps mentioned, showing that three times more light may be produced from a given quantity of oil, if its energy is converted first into mechanical power and then into electricity, than if the oil is directly burned in a lamp."

THE MANUFACTURE OF MILK SUGAR IN SWITZERLAND.

By A. Sauter.

IN a communication to the *Schweizerische Wochenschrift für Pharmacie* for the 20th of October, the author gives an account of a visit to Marbach, in the canton of Lucerne, Switzerland, where half-a-dozen refiners are said to make a handsome income from the manufacture of milk sugar.

The raw material used for the re-crystallization comes from the neighbouring Alps, in the cantons of Lucerne, Berne, Schwyz, &c.; a considerable quantity is supplied also by Gruyère. It is the so-called *Schottensand* or *Zuckersand*, the French *dechet de lait*, obtained by simple evaporation of the whey after cheese-making. Notwithstanding a continual rise in the price, consequent upon the demand and the increased cost of labour and fuel, the manufacture continually expands, and now amounts to 1,800 or 2,000 cwts. yearly, corresponding to a gross value of about 300,000 francs,—certainly a handsome sum for a small mountain village with but few inhabitants.

The manufacture is only carried on in the higher mountains, because there the material can no longer be used profitably for the fattening of swine, which are found chiefly in the valleys, and the wood required for the evaporating process is cheaper in the high lands.

The crude material is sent to the manufacturer or refiner in sacks containing one to two hundredweights. It is washed in copper vessels, and dissolved to saturation at the boiling temperature over a fire, and the yellow brown liquor, after straining, is allowed to stand in copper-lined tubs or long troughs to crystallize. The sugar crystals form in clusters on immersed chips of wood, and these are the most pure, and therefore of rather greater commercial value than the milk sugar in plates which is deposited on the sides of the vessels.

In ten to fourteen days the process of crystallization has ended and the milk sugar has finished growing (*ausgewachsen*). The crystals are then washed with cold water, afterwards dried in a caldron over a fire, and packed in casks holding four to five hundredweights.

As the *Schottensand* can only be obtained in the summer, the re-crystallization is not carried on in the winter; hence a popular saying that the milk sugar does not "grow" in the winter. The entire manipulation is carried on in a very primitive manner, it being a matter of astonishment to find a specific gravity instrument in any place. The author is of opinion that with a more rational method of working a whiter and finer quality sugar could be produced.

NEW MATERIAL FOR THE MANUFACTURE OF PAPER.

UNDER the title of "Nouvelle pâte à papier," we find in the "Explorateur" a letter of M. Joly, a corresponding member of the "Société de Géographie Commerciale," relating to the manufacture of paper with a new pulp of wood.

M. Joly says that, for about the last ten years, *savants* have been busily looking for products to replace the materials that have been until now acknowledged as the only ones adapted to the manufacture of white paper. They have at first naturally looked among the white woods. They have tried the pine, the fir-tree, the willow, the birch-tree; but none of these sorts gave the result which is obtained with the aspen-tree (*Populus tremula*). The pulp of aspen, according to M. Joly, is that which is nearest to the rag pulp. The industry created by the introduction of this new pulp took, especially in the Vosges, a rapid extension in a few years, and the business it gave rise to is valued at 3,000,000 francs.

Here are the various processes of disaggregation of the aspen wood used at the present day: each of them supplies a peculiar product:—

1. *Chemical Wood Pulp.*—The aspen wood is put in large boilers with chemical substances for twenty-four hours, and is subjected to a pressure of from eighteen to twenty atmospheres. This process supplies a pulp with long filaments, very tenacious, and easily blanched. It is adapted to the maufacture of white paper, and even of writing paper; but its high price has prevented it until now being worked in France; England, Sweden, and Norway having nearly the monopoly of it.

2. *Wood Pulp manufactured by the Aussedat and Bourdillat Process.*—The wood is cut into billets, and washed with steam during several hours: it thus becomes softer and easier to work. It is then rasped with a very hard grinding-stone of free-stone. The pulp resulting from it may be mixed with rag pulp in the proportion of 80 to 90 per cent. Paper manufactured with the aspen pulp only has a brownish hue, and, until now, could not be whitened.

3. *Wood Pulp by the Wœlter Rasping Process*—The wood is directly submitted, and without preparatory boiling, to the action of a grinding-stone rapidly turned. The product resulting is then chemically treated, and gives a white pulp. This pulp may be used, to the extent of 33 per cent., in the manufacture of letter paper; but it has little force and resisting power. The rasping is expensive; a one-horse steam power, working twenty-four hours, cannot rasp more than 10 to 12 kilogrammes of aspen wood.

To get the best possible results, it is best that the wood should be worked as soon as possible after it has been cut down; the drier it is, the more its hue becomes yellowish.

M. Joly concludes in the following words:—"Such are the present conditions of this manufacture. They are comparatively good, for this industry reaps money; but there are better hopes for the future, science having not said its last word with respect to it. It is believed, as previously stated, that any white wood may be used, and trials are daily made for this purpose; all may be adapted to the manufacture of good paper. As our forests are abundant in woods of this kind, we may rest quiet for a long time as to the manufacture of our paper—a symbol of modern civilization." *Moniteur Industriel Belge, Sept.* 1, 1876.

ON THE CONVERSION OF PEAT INTO FUEL AND CHARCOAL.

AT a meeting of the Society of Engineers, held on Monday evening, November 6th, a paper by Mr. Charles E. Hall, "On the Conversion of Peat into Fuel and Charcoal," was read. The author stated that his object was to place on record the cost and value of peat fuel and charcoal, to describe the best machinery and processes for producing them, and to draw attention to the superiority of ground charcoal for dust fuel in many metallurgical operations. The author first noticed the difficulties attending the working and manipulation of peat in its crude state, and briefly explained why certain methods of treatment had proved failures, and, by samples, pointed out the superiority of the system of condensation over that of compression. He then described the Lead Company's peat works at Middleton-in-Teesdale, showing the lowest cost at which peat fuel can be made under favourable circumstances, and giving the cost of working and production per ton for the last four months. The author referred at considerable length to the drying difficulty, and made some suggestions for the improvement of the process, showing the fallacy of artificial drying. A new system—or rather an improvement on the existing system—of condensation, designed by the author and Mr. Bainbridge, illustrated by diagrams and working models, was next brought before the notice of the members. The author described this operation as condensation by freely bleeding the peat, and this was stated to be very effectively done by the machine described, the samples showing how thoroughly the fibres had been cut up and disintegrated. This improved machine is intended for the production of the densest charcoal, fit for any metallurgical operation. Samples of finely-powdered charcoal, suitable for ironfounder's blacking, were exhibited, also samples for sanitary and agricultural purposes. The continuous peat carbonizing process was explained by the author, and a cost sheet, showing the probable cost of manufacturing charcoal on a large scale, was given. A novel construction of common fire-grate, suitable for economically burning peat or other light fuel, was also described.

BELL-METAL.—A new alloy for bell-metal is proposed, which does not tarnish, is less likely to crack, gives a better sound, and is much lighter in weight than the alloy usually employed for the purpose. It is prepared as follows:—Nickel, 1 lb. and copper 6 lb. are melted and cooled. Add zinc 1 lb., aluminum ½ oz. Melt and cool. Melt again, and finally add ½ oz. quicksilver and 6 lb. melted copper.

BY FAITH I OBTAIN

LATHES AND TURNING.

THE Company of Turners includes in its fellowship at the present time the Baroness Coutts and the Right Hon. W. E. Gladstone, and the craft itself dates from the remotest antiquity. Pliny mentions the lathe in his History, and gives the date of its invention as 600 B.C. Stow writes that they had "long continued a loving Fellowship or Brotherhood among themselves to the good example of others, and that because of this virtue they were incorporated among the companies of London in the Second Year of King James."

The art of turning has been associated from time immemorial with the material of wood, but it must not be overlooked that its ancestor was the potter. All things seem to have come from the clay. The potter was the first turner: that rude manipulator taught the sculptor and designer where to find in nature the substance on which they could operate. From his example the beauteous work of the designer and the grace and force of the sculptor have sprung. The turner has exercised astonishing tact in treating the mechanical forces and compelling them into his service: thereby combining the beautiful and useful by common operations which permeate every form of practical, mechanical, and decorative art.

Accuracy and delicacy in mechanical operations cannot be assured independent of the lathe. The ancients knew this as well as the moderns, but the development of its functions has taken place since the invention of the steam-engine, and proceeded at an amazing rate, and the impetus is still unchecked. Mr. Northcott's recent book on Lathes and Turning[1] has nearly four hundred illustrations, and might have had double the number without exhausting the supply. Even the fine folio of R. P. Charles Plumier, "L'Art de Tourner en Perfection," &c., 1749, has eighty full page plates, and the modern work of Mr. Holtzapffel would have required a large number if it had ever been completed, for its author intended to treat the whole business in the most thorough manner. That has been practically done by Mr. Northcott, and the work he has produced warrants public

Fig. 1.

confidence in the fidelity and excellence of his labour. As the author says, "Proficiency in this most useful art is not to be acquired from books alone, but I believe the information given in the following pages may be taken as sound and practical."

The lathe is now employed on materials gathered from the vegetable, animal, and mineral kingdoms, and in the mechanical arts its use depends upon the structural difference and physical character of those materials which, when selected, require peculiar modes of preparation, working and joining, which need not here be described. To reduce these diverse elements to its control an infinite variety of tools, contrivances and machinery have had to be invented and are being invented. Fine woods are perfect and imperfect: sometimes duly seasoned and sometimes not; prepared they should be, but it happens that occasionally that cannot be. Then they are hard or soft, dense and durable, or otherwise—they may be elastic or stubborn—they may need softening or bending. Then for ornamental turning woods of various colours have to be collected, and their fibre, knots, curls, silver-grain, well understood before the machine can touch them, and even then specially contrived tools made for their treatment—tools of every degree of hardness and every variety of form and edge—have to be selected.

In the animal kingdom a like variety is observable. In our notice of Sheffield productions (October, 1876) reference was made to these. The lathe treats shells, horns, tortoise-shell, all the kinds of ivory, recent and fossil, turning them into veneers cut spirally, or producing quaint and beautiful articles of ornament or use in profusion, at once causing amazement and delight to the beholder. A fine example is seen in the accompanying illustration from works made by Mr. Baker (fig. 1). These it is evident require the most delicate and perfect of implements and machinery for their creation and consummate excellence and skill in the manipulation.

Then, lastly, we notice the use of the lathe in the treatment of minerals, in which we include earth and metals. Hard clays of every kind, meerschaum, amber, jet, alabaster, slate, marbles, spar, precious stones, all need different treatment, and even tools of various materials, for it is a fact that the ruby and diamond have to serve as instruments as well as material. Of metals there are already twenty sorts on which it is employed, and these vary in malleability and fusibility, whether as metals pure and simple or metals and alloys. The tools have to be adapted, not only in form and size, but in their tempering. Nor can this outline omit the enormous service of the lathe in the treatment of iron and steel, both hard and soft, hammered or crude. Where would have been Nasmyth's immortal hammer, the guns of Armstrong, Whitworth, and Krupp, but for its invention and development? It does what no plane cutting could effect, and with an equal perfection upon the delicate ivory and the 100-ton gun. It obeys the foot of a little child, and is capable of treating with ease substances that no human power could manage without its aid. The steam-engine itself, without which it could not have grown, is one of the most useful of its works. Wheels, axles,

[1] A Treatise on Lathes and Turning, simple, mechanical and ornamental, by W. Henry Northcott. Second edition. London: Longmans, Green, & Co. 1876.

bars, cylinders, most minute and most enormous, models as well as objects, are alike its fruit and its agent. Let us hastily run through its phases.

In the history of the lathe its constructional progress is remarkable for its rapidity, as will be seen by a comparison of the two lathes, figs 2 and 5. The former being the common form of the primitive hand lathe; the latter, one of the most elaborate machines of its kind worked by steam-power. It is but a little while ago that the hand-lathe was the sole form, and that is now employed almost solely by amateurs and turners in wood. They can be obtained for a few pounds; but a better one is made by Messrs. Eastonbrook and Adlard (fig. 3); still neither have much force, for although ample power may be available, it is spent before reaching the spindle, and there is but little scope for variety in its speed. A contrivance called a "slide-rest" marks its stage from the primitive construction to its birth as a modern machine. This slide-rest is a kind of mechanical hand for using the tools (fig. 4), and enables the operator to turn plane surfaces, taper shapes, parallel bars, &c., better and quicker than when the tool is held in the hands; but for especial purposes the hand is better. Slide-rests are of two kinds—guided by a wheel handle, or made self-acting. In the one case there is nothing to do but the adjustment, and the tool moves in the required direction; in the other, the motion of the lathe itself causes the tool to move. Of this last there are many inventions, but they are chiefly used in workshops for turning plain work.

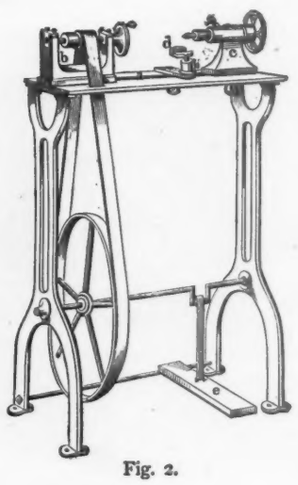


Fig. 2.

It is most important to the student to know exactly the meaning of the terms employed in mechanics. A man wishing to drive horses must know precisely the names of every part of the harness, and he who would guide machinery or know of it must ascertain what is meant by such terms as chucks, possets, rests, blanks, concentrics, gears, cranks, head-stocks, all mathematical instruments and tools, &c.—items that would require a two-page glossary—before he is qualified to read intelligently what is written for his instruction. This knowledge once gained opens a new world to any man, and the digression to say so must be excused.

Gentlemen who practise turning, and machinists that make large contracts, value very highly the self-acting screw-cutter. The principle is operative in two forms, and the amateur or mechanic will do best by consulting Sir Joseph Whitworth & Co., who have patented two—that for mechanics is in many forms, chiefly heavy and large, but the best is the Duplex lathe (fig. 5), while, for amateurs and light trade work, their 5-inch self-acting lathe for foot-power is esteemed the best (fig. 6). Some of these are of exquisite construction, and are used by ladies or by gentlemen amateurs in producing ornamental work requiring delicacy of touch to realize the taste of the operator. Most of these are driven by the foot in connection with a slide-rest. Muir & Co., of Manchester, have many excellent machines and contrivances as auxiliaries, and so have others.

No one should attempt to make a lathe; it cannot be done satisfactorily. Accuracy is the *sine quâ non*, now as in the days of Cicero, when, to describe anything as being just and perfect in form, it was usual to say, "It was formed in a lathe." If we consider the absolute demand for the finest adjustment, we shall not be surprised at finding the impera-

tiveness of purchasing a lathe and not making it. Look at that used by watchmakers. If that is beyond the amateur, so is the other, for the principle is precisely the same. While, in London, we have the Messrs. Holtzapffel for the higher examples, and Messrs. Maudslay for the heavy, and in the country the great houses named, and many others equally good, it is folly to occupy precious time in what must turn out a failure. The art is rapidly rising in popularity, and will be a great favourite among persons of leisure, as it was a century ago; and this makes it the more necessary to see that all the implements are of scientific construction.

It is more than sixty years since the favourite Rose engine lathe, or figure lathe, had a good sale under the first Mr. Holtzapffel, but it produced beautiful work. Mr. Northcott's book contains full instructions, examples, and counsels that make the whole art adapted to our generation, advanced as it is in the mechanical arts, and changed as it is in general taste. We add two examples of ornamental work (figs. 7, 8).

The combination of delicate machinery of modern invention is shown in another way. The circular saw is of modern date, but the turner finds he can apply it to the lathe in cutting up veneers, slicing ivory and hard woods, and such light work as can be done by the tread. Messrs. Booth, Brothers, of Dublin, have a little one of this kind (fig. 9). These again can be planed now by having a cylindrical cutter revolving rapidly between the lathe centres; and where moulding or grooving is

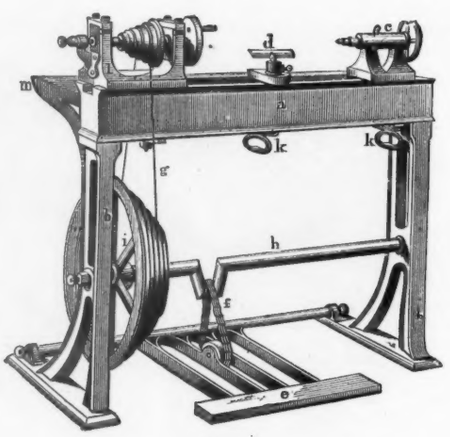


Fig. 3.

required, or fret-work for pattern making, or curved and angular work, a little saw-frame can be put on and taken off the lathe at pleasure (fig. 10).

Modern mechanists have made self-acting lathes of many kinds, but there is one designed as a universal lathe, inasmuch as many operations can be performed by its aid that are usually the work of two or more, or impracticable by any. It is a most useful machine to the engineer in his study for model-making, or to the mechanician for experimenting. "Self-acting" undoubtedly it should be designated, but experience alone will teach the hand of the operator how to employ it, and his eye how to observe the progress if the result is to be worthy. The machines are costly and require care. They are fine specimens of ingenuity and deserve it; but unless the entire management is painstakingly attended to, although the work will be free, it will be rough and unsightly.

There is a further development of the turning art in the wheel-cutting machine; a small apparatus, not expensive, but very convenient for wheel and also for other work. There were many of these aids to turning in the Loan Exhibition of Scientific Apparatus; tiny ones for cutting watch-wheels, milling, circular work, sent by Mr. Bodmer of Manchester; and in the 1862 Exhibition Messrs. Fairbairn exhibited the apparatus for their manufacture. But we shall have too long a catalogue if we name all the varieties which now exist and the range of their utility. In boring and drilling alone there are enough to fill page after page of matter and illustration. The minute and the enormous are alike dealt with by the lathe. The jewelled hole in a watch and the bore of the 100-ton gun must both be perfect; and if the engines or machines are properly employed the result is certain; but the attainment of this perfection in the art of

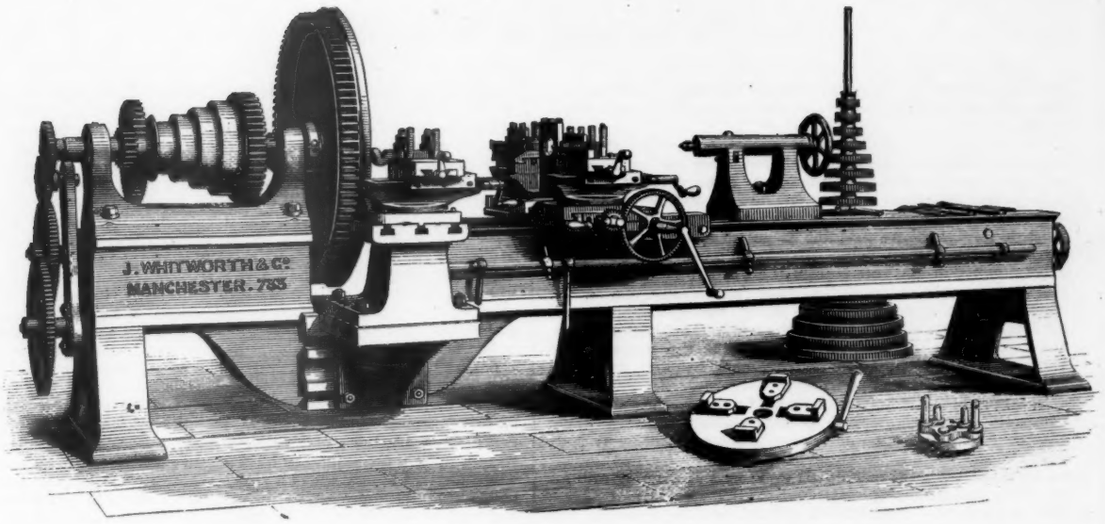


Fig. 5.

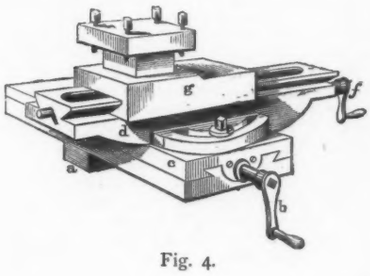


Fig. 4.

Fig. 9.

Fig. 10.

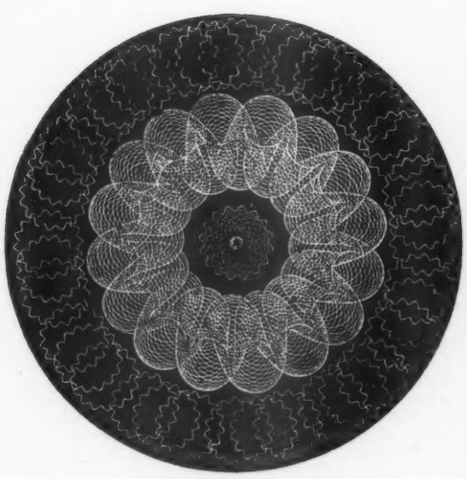


Fig. 7.

Fig. 8.

construction, and in the adaptation of mechanical forces has not been effected without immense labour, enterprise, and intelligence.

In the out-of-the way forms of the lathe is one for turning shoe-lasts, which is so constructed that, from one as a pattern, an exact facsimile can be formed from a rough block of wood. The pattern and block are fixed on one axis, and are made to revolve round a common centre in a swinging lathe; a sliding carriage is used, and the machine is put in motion. During the revolution the pattern, being irregular in its surface, causes the axis to approach and recede from the wheel, thereby presenting the whole surface to the friction-wheel, and in like manner the *block* is presented to the cutting-wheel, which, being of rapid motion, cuts away all that part furthest from the common centre, and in due time produces an exact copy of the model. This machine is now adapted for making oars, handles, and other articles with facility and perfection.

In large works the lathe is compound; that is, the parts are of multiform purpose—planing, boring, milling, facing, drilling, and the like. The enormous weights necessitate this to save time and risk; and it costs little extra to add to the capabilities; for instance, when the machine is to be used as a boring-mill for cylinder-making, the slide-rest and shifting-stock are removed, and the boring-bar substituted; and so is it in other cases. The principle could not be utilized on another method, and its operation in such diversity is both amazing and interesting.

Two or three remarks must close this notice. It is a great drawback to the cultivation of the art of turnery, whether for trade, amusement, or education—and in all these there is much to be said in its favour—that the instruments and tools are so costly. It does seem excessive to be charged shillings when pence ought to do as well. The processes by which steel is treated are reduced in cost more than three-fourths, and the tools, &c., are doubled in price, while the demand is steadily progressing and increasing in activity. Unless English manufacturers take warning, France, America, or Germany will assuredly enter into a sharp competition that will not have much sympathy from the mechanical world or the school of political economy.

And in closing Mr. Northcott's book it is our duty to acknowledge the obligation of the public to a valuable contribution by Mr. James Nasmyth on "Hardening and Tempering Steel Tools," wherein he shows the primary importance of proper forms, and their capacity for retaining a cutting-edge. He points out that when the steel has to be treated it can not exceed bare red-heat without injury to the quality; and that in forging, the finishing blows must be given on the flat, not on the side, in order to increase its durability. "Tempering" is the modifying process to harden or soften for given purposes, such as toughness. He advises previous grinding so as to produce brightness, and then resting it on a piece of red-hot iron; and describes the stages of colour that process will create, and the application of the tools to the various materials wrought upon; recommending especially to the amateur the employment of two or three hours a day in experimenting and practising these counsels.

In this second edition of a book, which is one of the standards in the craft of which it treats, the information is brought up to the present time, ninety-nine of its numerous illustrations being new. Of the quality of the illustrations the specimens we are enabled, by the courtesy of Messrs. Longmans and Co., to present will be a sufficient testimony.

THE NORTH SEA CANAL.

THE great ship canal which connects Amsterdam with the North Sea was opened by the King of Holland in person on November 1. This great enterprise, in which English engineers have had a large share, and which has been constructed by English contractors, is of vast importance to Dutch commerce. It will be open to the commerce of the world at a tariff per ton which hardly seems enough to provide for the maintenance of the lights, banks, and locks. But the undertaking was not projected for the sake of immediate gain; and in guaranteeing the interest on the shares for half a century in advance on certain conditions, the Government recognized that the benefit to accrue to the country and to the city of Amsterdam was worth purchasing at the national expense. The great port of Amsterdam, which sprang into sudden importance when the Spaniards had ruined Antwerp, had begun during the last few years to see before its eyes the danger of its joining the melancholy sisterhood of the dead cities of the Zuyder Zee. The channels by which the riches of the world were once brought to Amsterdam, to be re-shipped at the profit of the Dutch capitalists, have become too shallow for the vessels of great burden which carry the merchandize of modern days; and even the spices of the Dutch East Indies, the coffee of Java, the sugar, indigo, tobacco, and rice from the tropical dependencies of Holland in the East and West, go now by preference to Rotterdam, which has long been growing at the expense of its more famous neighbour. The old route from Amsterdam to the ocean was by the Zuyder Zee; but the storms and sandbanks of this dangerous gulf led, in 1819, to the construction of the North Holland Canal from Amsterdam to the Helder, the northernmost point of the province of North Holland, and over 50 miles from Amsterdam. Why this route was chosen instead of the short cut now made, it is hard to understand. William I. is said, when the plans were brought to him, to have struck his pen boldly from east to west along the line now taken by the new canal, and to have remarked that this was the true course to the sea. But provincial interests prevailed over the claims of the mercantile capital, and it was reserved for our own days to bring Amsterdam by a cut of 15 miles within an hour or two at ordinary tides of the German Ocean. What the effect will be upon the commerce of the world must be left to time to determine. The citizens of Amsterdam possess shrewdness enough to offer a formidable competition to any rivals in trade, and they possess great accumulations of capital. For all kinds of traffic, except that in stocks and shares, they have hitherto in recent days been heavily weighted. It takes one or two days for large vessels to reach Amsterdam from Nieuwdiep, as the port of the Helder is called, and they often suffer much longer delay from contrary winds. They cannot come at all till they have been relieved at Nieuwdiep of part of their cargo, which is sent on by lighters. The result is, that charter-parties often contain an express stipulation to the effect that though the vessel may be ordered, perhaps, to any part of the British Isles or on the continent of Europe between Havre and Hamburg, she shall not be compelled to go to Amsterdam. The new canal will probably put an end to this invidious exception. For many parts of Germany and for Russia Holland is very favourably situated to act as an *entrepôt;* but even the port of Rotterdam is not without its shallows, and the country has not in modern days had a fair chance in the competition with London, Liverpool, Hamburg, and Bremen. Much was hoped from Flushing when expensive quays were constructed there, but there is comparatively little capital at Flushing, and Dutchmen nowadays are intensely stationary, otherwise the wealthy classes must long ago have quitted a country where men live, as Erasmus says, like birds, on the tops of trees, being obliged to drive whole Norwegian forests of piles into the ground before they can even build an hotel. Amsterdam will not go to the sea, but the sea has been brought to Amsterdam, and it will be most interesting to watch in the next few years what use will be made of the recovered advantage.

In 1500 a Dutchman proposed a canal for drainage between Amsterdam and the west coast; but the first spade for making the present canal was put in the ground in March of 1865. The late Minister, Thorbecke; the president of the company, Mr. Jitta; the engineers, Sir John Hawkshaw, our countryman, and Mr. Justus Dirks, of Amsterdam, and the contractors, Messrs. Henry Lee and Sons, of Westminster, have been foremost in the struggle which, lasting for a longer period than the Trojan war, has now nearly come to its termination. The canal is not yet so wide throughout as it ultimately will be, and the harbour is far from complete. The harbour is to afford berths for 300 large vessels, and will probably be very useful on that exposed coast, which is at present entirely unprovided with a harbour of refuge. A number of small fishing vessels obtained shelter in it in a recent gale. A channel in which large vessels can pass each other is opened through the uncompleted harbour to the canal.

A special department of the Government service, called the Waterstaat, is employed in watching the state of the waters in Holland, and in guarding against irruptions—a duty upon the due discharge of which the very existence of Holland depends. Mr. Boogaard, permanent chief financial adviser of the Ministry in these matters, and Mr. Conrad, a chief engineer of this State Department, will have, on the part of the Government, the control and inspection of the new canal, which will continue, however, for the present at least, to be managed, under their supervision, by the company. Side by side in the long dike (nearly a mile long) are three locks for ships, one sluicing lock, and three channels of masonry for pumping out by steam the water when, as is usually the case, the tide in the Zuyder Zee is higher than the water in the canal. The largest ship lock is 315 ft. long and 59 wide; the length of the other two is 239 ft., and their width 46 ft. The locks are built on 8,896 piles, and the dike on mattresses of fascines laid on the mud. The sea bed was from 12 ft. to 27 ft. below the surface of the water; but firm

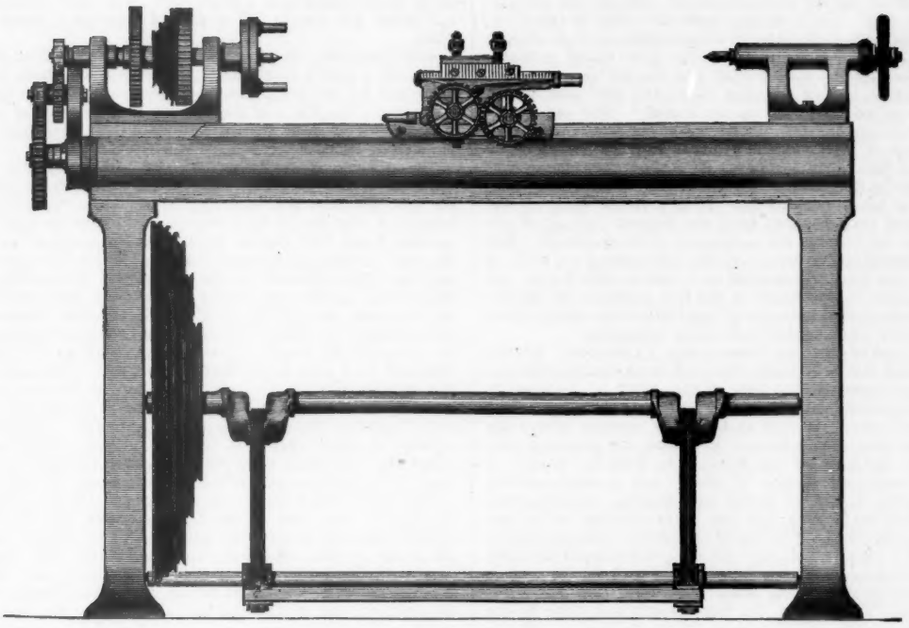
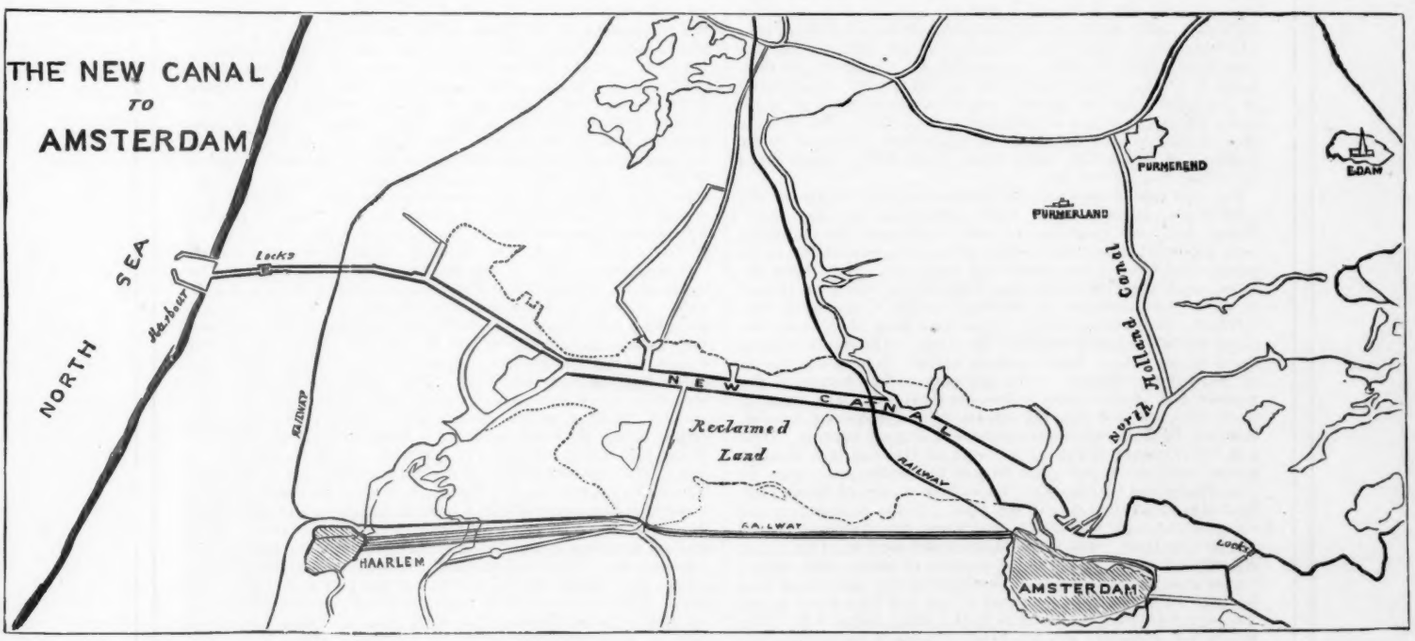


Fig. 6.—Lathes and Turning.



The North Sea Canal.

ground was in some cases not found till a depth of 60 ft. below the water was reached. The dike is of sand and clay laid on fascines, faced on the sea side with blocks of basalt and granite, covered with clay. The locks were opened in 1872 by the King, and since then have given passage 200,000 times to craft of more or less importance. A shallow lake, the Y, so called, perhaps, from its shape, used to extend from the Zuyder Zee to within three miles and a half of the west coast, and this part of the country was called "Holland op zijn smalst." The old North Holland Canal may be seen as one leaves the quay opening on the north bank of what was the Y and is now the canal. The old width has been preserved here. It is about the same as that of the Thames at Gravesend. On the south a great central railway station is being constructed. It is a house built on the sand, the sand brought down from the western cutting of the canal. Here the channel did not require to be deepened. The Y used to expand to the west, and the tide rushing out of it at ebb scoured this narrower channel to a considerable depth. An unfinished polder to the north is the first example of that remarkable system of reclamation of land which has alone, by its financial results, enabled this canal to be completed.

The gross cost of the canal is more than £2,000,000. But the net cost in cash will be probably not much more than £1,000,000. The sand excavated in one part of the canal is conveyed in barges and deposited on the muddy bottom of the lake. That is covered with clay. As soon as the bank appears above the surface of the water and is formed, the slopes are protected with fascines from the wash of the waves. At first the bank is a division between two masses of water—one a comparatively narrow channel the other broad but shallow. Archimedean screws are now set to work, and the water is forced out of the expanse into the canal. The bed of the ancient lake becomes a meadow and is called a "polder." All along the sides of the canal stationary steam-engines have been erected to keep the polders dry by constantly raising the water from them and pouring it into the canal. The work in the first instance was done by the Archimedean screw. The polders have realized at Dutch auction an average of £80 per acre, and are not all sold. Some parts near Amsterdam, and valuable for building purposes, have brought £340 per acre. For agricultural purposes £120 an acre has been paid. The total amount reclaimed and to be reclaimed is 12,450 acres. Some 8,500 have been disposed of. The polders are usually sown with cole seed in the first instance. Excellent crops of rape, colza, wheat, and vegetables are now growing on land which two or three years ago was at the bottom of a lake. This reclamation of polders is by no means rare in Holland. It may be said that the greater part of the country has thus been rescued from the water. Everywhere you see low meadows thick with cattle, while above them tower the banks of the canals. The barges float above the chimneys of the houses. All the cows have a kind of railway rug comfortably strapped upon their backs to protect them from the cold and the damp. The raising of the water from the polders was formerly effected by windmills, but steam is largely superseding them now. The tenants elect trustees to keep the banks in repair and contribute to the expense of lifting the water from their fields quotas fixed according to a general law.

On each side of the canal the polders continue nearly till the sand-dunes are reached, at three miles from the west coast. Before this point there may be seen on the north the multitudinous windmills of Zaandam, which grind paint, saw timber, make paper, chop tobacco into snuff, beat hemp, &c. Here Peter the Great spent a few days learning shipbuilding, before he retired to the private dockyard of the Dutch Indian Company at Amsterdam. Large ships are no longer built here, but it is not the canal which has interfered with the trade. The rights of those living by the Y have been carefully saved. Side-canals run to all the fishing villages. Tolls are only to be charged at the western end of the canal, so that the local traffic will continue to be free, and will reap the advantage of a deepened channel. Another class of rights has been saved at great expense. The Lake of Haarlem, famous in the wars of Holland, was drained a few years since, and great part of the waters were year by year discharged into the Y. The surface waters of North Holland also found their way to the lake. It was provided in the Canal Company's concession that these arrangements should not be disturbed. The corporations which kept the Rijn Land, &c., dry are not to be put to the expense of raising their waters higher than they did before. The water in the canal must thus be kept at least below the level of the old high-water mark. The exact height prescribed is half a metre below A.P. The letters A.P. represent the height of an ancient Amsterdam pile which was in its time the mean between high and low-water mark. The tides are two or three inches lower now. To maintain the prescribed level it is necessary to pump the water from the canal into the Zuyder Zee. For this purpose three engines by Eastons and Anderson, each of 75-horse power effective, have been established at the Schellingwonde or Orange Locks. They drive three centrifugal pumps, and raise 2,000 tons of water 19¼ inches per minute. The area of drainage is about 300,000 acres.

After Zaandam, the most important place passed on the canal is Velsen, a pretty rural village, the charm of which has been destroyed by the tugs, stationary engines, and mud barges of the canal. On the way down, tugs with batches of ten mud barges each in tow, buttied two by two, are passed without slackening speed.

Three kinds of dredgers are seen. The ordinary bucket-dredgers, discharging into mud barges have been largely used; but also the mud has been discharged into a vertical cylinder, whence it was forced by a Woodford's pump through floating wooden tubes with leather joints, and so conveyed at once to the land. A third arrangement was made by Mr. Darnton Hutton, who has superintended for the contractors the construction of the harbour, as the construction of the canal has been directed for the same contractors by Mr. T. C. Watson. According to this arrangement water and sand mixed together are sucked up by a centrifugal pump; the trunk let down to the bottom is attached by a joint to the dredger; 1,200 to 1,500 tons of sand in a working day are thus excavated by one dredger with a 20-horse power engine. At Velsen the canal is crossed by a bridge. Near Zaandam there is also a railway bridge. They are both capable of being opened to let vessels pass. There are also, where the side canals enter the main canal, bridges for the purpose of the towing-paths, which are continuous on each side.

Soon after Velsen the dunes commence. These sand hills are common to the coast of the Low Countries, and as the sand blows from them in sufficient quantities to fill the ears and sting the faces of those who walk on them, it has been commonly said in Holland that they would fill up the canal. Sir John Hawkshaw, who reported in favour of the Suez Canal when its maintenance was pronounced impracticable for this very reason, and by eminent engineers, was not deterred by a danger which is much less in Holland than in Egypt. The danger would be greater if the dunes were not held together by a slender reed called "helm" (*Psamma arenaria*), which is planted on all the dunes in the country, to arrest their gradual march into the interior. A more real evil is the tendency of these loose banks to be washed in by the action of steamers. To correct this tendency the banks are lined with broken brick, stone, fascines, and clay. Thirteen hundred yards before the sea is reached are the North Sea Locks. The north-west wind urging the waves round the coast of Scotland brings into the German Ocean a mass of water which is hindered in its passage to the south by the narrowness of the defile in the Straits of Dover. Such a wind lasting for days piles up the sea-water to an extraordinary height against the coast of Holland, and is the most formidable enemy of the country. The inundations which in the thirteenth century destroyed thousands of Frisian villages to make the Zuyder Zee were due, doubtless, to such causes. Great precautions are used at the western end of the new canal to prevent the new channel now opened from facilitating any such irruption of the sea. The locks are unusually high and strong, and provided with extra gates, to be used when the tide is more than 1·50 metres above the level of the Amsterdam pile. When it reaches 1·75 metres above this height the lock gates are not permitted to be opened at all. At ordinary times very large vessels can pass these locks. There are two locks and a sluice. The larger of the two locks will admit a vessel 393½ ft. long and 59 ft. wide. Its sill is 28 ft. 8 in. below ordinary low water. Outside these lock gates there is a short tidal passage to the harbour. The harbour is being built out of concrete blocks, made near Velsen by the contractors, out of Portland cement, sand, and gravel brought from the Rhine. Two moles, which start at the sand-hills, 1,313 yards apart, extend each 1,600 yards into the sea and converge, so that the entrance is 284 yards wide. An elliptic space enclosed by them is being dredged to 26 ft. 3 in. below low water. About 135 acres are to be so dredged at first. The concrete blocks of which the moles are built weigh from six to ten tons each. The sandy bottom on which they are founded is first covered with a layer of basalt rock brought from the Rhine, about 40 yards wide and about one yard thick. This stratum was kept 200 or 300 yards in advance of the pier in construction, so as to be well embedded in the sand and settled to its proper place before the foundations of the pier were laid. The basalt rubble is levelled by divers, and the concrete blocks are set upon it by an immense travelling crane or Titan, running on rails on the completed portion of the pier. The mole is thus in general built up to 13 ft. 6 in. above the Amsterdam pile. The piers are 27 ft. wide at the top, and increase in thickness downwards by one-seventh of their height. There are two lighthouses on land, besides the pier-head lights. The two piers are each

but 60 yards less than a mile long, and the construction of each requires 433,600 yards of blocks, 77,700 tons of cement, 299,000 cubic yards of shingle, 130,900 cubic yards of basalt, 9,035 of ballast, 34,611 of broken bricks. This great harbour is entirely of English design (Sir John Hawkshaw's), and is built according to English methods by Henry Lee and Son—the same contractors who constructed the Dover Admiralty Pier. Further to secure the moles against the billows, a slope of rocks is thrown into the sea on the outside of each pier. The lower blocks of these wave-breakers are 10 tons each in weight, and those above low water weigh about 20 tons.

The canal was excavated by dredging, except that part where it passes through the *dunes;* there the spade was used first and the dredger afterwards. From Schellingwonde Locks to the sea it is 16 miles long. These locks are to the east of the city, and the distance from the principal quays to the German Ocean by the canal is only 14¼ miles. The channel is 88 ft. 6 in. wide at the bed, and 207 ft. wide at the surface. The depth when the canal is completed will be such that vessels drawing over 23 ft. can pass throughout; but this depth is not reached at present. Ultimately, the canal between the North Sea Lock and the sea will have a depth of 8·56 metres below the Amsterdam pile, and the width of the canal will be 35 metres at the bottom; and, ultimately, the canal from the North Sea Lock to Amsterdam will have a depth of 7·70 metres below the normal water level. There are ten collateral canals, of an aggregate length equal to that of the main canal. The length of banks in the whole set of works, including polders, is 40 miles, and the excavation has been to the amount of 13,000,000 cubic yards. While considerably shorter and a trifle shallower than the Suez Canal, this is wider, and contains engineering works, in its dam at the east and its locks at the west, which the famous work of M. de Lesseps is entirely without. The desolate sand-hills at its eastern end have been unfavourably compared with the busy town of Suez, but the more sanguine expect a fashionable bathing place to be speedily established here under the name of Ymuyde, "the mouth of the Y." A regular line of two steamers a week is to run through the canal to London.

The financial arrangements by which the large sums required for the construction of the canal were procured are full of interest, though they are rather intricate. The original share capital was 15,000,000 florins, on which the Government guaranteed an annuity of 4½ per cent. for 57 years in case the canal was duly made. Of this annuity 4 per cent. was designed to be applied in payment of interest, and ½ per cent. in gradual extinguishment of the shares by purchase. The florin may be reckoned as worth the twelfth part of a pound sterling. Besides its guarantee the Government gave a subsidy of 3,000,000 florins, and the town of Amsterdam contributed an equal sum. Each of these subsidies was afterwards doubled. There was a very critical period when the shares were only worth 33 to 35 per cent., and in large quantities were not to be disposed of. The contractors had taken 10,000,000 florins' worth of them at 75 per cent., and had dealt with 3,500,000 florins' worth of them by sale or mortgage on reasonable terms. But now they had on hand 6,500,000 florins' worth of shares practically not negotiable. At this moment much financial ingenuity was shown by the managers of the company. They took advantage of an insufficient stipulation in their concession to obtain a measure which much increased the credit of the canal. The concession provided for the construction by the company of one lock at Schellingwonde. But it became obvious to those interested in the navigation that with only one lock great delay would be caused in the passage of ships, and this was so strongly urged that the Government offered to atone for the omission in the concession of any further facilities by itself constructing three locks at the national expense. To this the canal company refused consent, and ultimately it was arranged that the company should build three locks, but that the Government in return should assist in the disposal of the 6,500,000 florins' nominal amount of shares, by guaranteeing them absolutely, and allowing them to be issued as bonds. The guarantee previously given had been conditional and temporary. The new bonds were offered to tender, taken up at 88, and now stand at 95, or par. The ordinary shares rose at once, and are now worth 67.

The issue of 10,000,000 florins of bonds, secured upon the reclaimed lands, was also authorized by the concession; but the land sales will bring in more than this amount. The whole nominal cost of the works is 37,000,000 florins, made up of 8,500,000 in guaranteed shares, 6,500,000 in guaranteed bonds, 10,000,000 in land bonds, 12,000,000 in subventions. To reduce the large amount outstanding, the shareholders have agreed to accept 3½ per cent. annual interest in lieu of 4 per cent., and 1 per cent. is annually applied in purchasing shares in the open market for cancellation. These operations will make it easier by degrees for the Government to buy up the canal and extinguish the tolls. The tolls at present for the whole passage are 72 Dutch cents for ten cubic metres, which amounts to about 4½*d.* per registered ton. The harbour dues are 4 cents, that is, four-fifths of a penny. The canal tolls are, however, reduced by one-half in favour of vessels which arrive from any port north of Brest. This provision includes British ports, and is made because such vessels are expected to make frequent trips.

The Minister of the Interior has announced that vessels of 5 metres draught (16 ft. 5 in.) will be admitted into the canal at all times except low water, and at low water vessels of 4·20 metres (13 ft. 9 in.) draught. Thus commences the history of the principal engineering scheme of modern Holland, the successful working of which will prepare the way for the next great undertaking, the recovery of the valuable territory at present sunk beneath the brackish waves of the Zuyder Zee.

Chemistry applied to the Arts, Manufactures, &c.

ABSTRACTS FROM FOREIGN PERIODICALS, TRANSACTIONS OF SOCIETIES, ETC.

MANUFACTURE of White Lead.—The process followed for the manufacture of white lead, and the one explained in all the handbooks of chemistry, is the one known as the Dutch process. The use of petroleum to prevent the lead-poisoning of workmen is a useful fact for manufacturers. M. Fastré verified that most cases of lead poisoning of his workmen resulted from the absorption of white lead through the pores of the skin. He remarked that men at work with the scrapers, or the horizontal grinding stones, are affected, as well as those who pound the white lead; and yet the scraping and water-grinding produce no dust. In such work it is through the absorption by the skin the poisoning is effected. M. Fastré found in petroleum an energetic auxiliary to prevent the cases of poisoning. Before beginning work, at midday, and in the evening, the workmen are obliged to wash their hands with petroleum. For one year they have done it, and they have been very seldom ailing. The cases of lead-poisoning have decreased 90 per cent. The workmen busy with pounding are alone in danger. All the workmen take this work by turns. Soon every cause of insalubrity will disappear by the installation of a ventilator. Benzole, existing in the petroleum, scours the skin, and takes the white lead completely away; the fat substance in the oil prevents the absorption of lead-salts during work. This simple process, which is said to give such good results, may supply useful applications in many industries where the workman has to handle salts of copper, mercury, and other such products. *Revue Industrielle, Sept.* 6, 1876.

Honey, and its Adulteration.—By M. MAX SINGER.—The production of honey is well known. Good honey is transparent and fluid when recently collected. Afterwards it becomes formed into grains of average size, which are soon of a translucid white colour. Its smell is sweet and aromatic; it must not have any peculiar taste, and not affect the throat. The first quality honeys in France are those of Narbonne and Chamounix; those of Gatinais are slightly inferior to the latter, having a rather different taste and aroma. Finally, the honey of Brittany is of an inferior quality; it is of russet-yellow colour, with a strong smell and a characteristic taste. Good quality honey is purified by mixing with it 4 to 5 per cent. of charcoal, and beating it with water and some white of eggs to clarify it; then it is passed through filters which contain a mixture of animal and vegetable charcoal in grains, the effect of which is to take out the colour and take away any bad taste. Starch, French beans, meal, sand, gum, mucilages, gelatine, are used to increase the viscosity of adulterated honey as well as its volume. Such frauds are easy to detect. Instead of being liquefied under the influence of heat, adulterated honey becomes thick and very dense; if, afterwards, it is treated with cold water, the only residuum remaining consists of extraneous matters, such as sand, French beans, meal, starch, &c., which are coloured blue by iodine water. The most simple adulteration, which consists of merely the addition of water, is easily detected by ascertaining the density of the honey:—7 decilitres of genuine honey weigh 1 kilogramme; consequently, 7 decilitres of honey adulterated with water, will weigh less than a kilogramme. *Technologiste, Sept.* 2, 1876.

Manufacture of Melon Sugar.—The *Messager Franco-Américain* informs the industrial and commercial world that a company has just been formed in California for the manufacture of melon sugar. The water-melon is, it appears, much superior to beetroot for the manufacture of sugar. Its cultivation is less expensive, and the reduction is carried out at less expense. The purifying of the pulp of the water-melon requires almost no work; there is no necessity for acid, and a small quantity of animal charcoal and lime is sufficient for the operation. Contrarily to what occurs with the beetroot, the melon, before being sent to the mill, does not want to be washed, and the juice it produces does not become black, and may be preserved some days without fermentation. The cultivation is also much more simple. Besides, the fruit supplies a syrup fit for immediate consumption, and from its kernels an excellent salad oil is extracted. The residuum, sufficiently nutritious, is advantageously used as a food for cattle. It is prudent, perhaps, not to accept this information without some reservation, leaving to sugar manufacturers the task of ascertaining its correctness. *Technologiste, Sept.* 30, 1876.

Tempering of Small Steel Articles in Spermaceti Oil.—By melting together 4 or 5 litres of spermaceti oil, 2 pounds of tallow, and $\frac{1}{4}$ pound of wax, a mixture is obtained very convenient for tempering any kind of steel articles of small size. Adding one pound of resin, it is used for the tempering of larger articles. The addition of resin must be made with care, for an excess of this material renders the steel too hard and brittle. After several months of use the mass loses its energy; it must then be wholly renewed, taking care to thoroughly cleanse the bottom of the tub which contained it. Another mixture, of which practice likewise has proved the efficacy, consists of 90 litres of spermaceti oil, 20 pounds of tallow, 45 litres of ox-foot oil, 1 pound of pitch, and 3 pounds of resin. The pitch and resin are melted together, then the three other materials are successively added, and the whole is heated in an iron pot till all the water is evaporated. This is ascertained when the mass takes fire at the approach of a burning chip of wood; the flame is put out by hermetically shutting the pot with a cover. Here is the way in which the tempering is effected in both cases:—

Saw blades, for instance, are heated in special ovens, and when they have reached the convenient temperature they are dipped in the mass, contained in tubs arranged side by side. For a continuous manufacture a certain number of tubs are used, so as to allow the mass time for cooling during the progress of the operation. As soon as the blade is conveniently cooled, it is withdrawn from the bath and cleaned with a piece of leather, so that there remains still on it a thin layer of grease. It is then passed over a coke fire till the grease catches fire and burns with a clear smoke. In this way the blade acquires convenient elasticity. If it is wanted to have it very hard, a part only of the grease is allowed to be burnt; the more softness is desired the more the burning is completed. For springs the flame is left to burn itself out. If the objects are of various forms and sizes, the burning is repeated on the several parts till all the parts are deemed equally tempered. The blades are finished by hammering and heating them again on a clear coke fire till they return to a straw yellow hue. The coloration is then taken away by washing in diluted hydrochloric acid, and afterwards in plenty of water. *Rev. Industrielle, Nov.* 1, 1876.

Tempering Steel in Mercury.—It is generally admitted that the hardness which steel may acquire by tempering is so much greater as it is more rapidly cooled by the tempering. Water, more or less mixed with saline substances, is the liquid most in use, and it must be confessed that it is not at all convenient. It must give but an unequal temper, and the steam bubbles developed by the heat often prevent the contact. We must add, however, that water being a bad conductor of caloric, it would be absolutely unfit for temper if it were not equably agitated by ebullition. Water mixed with ice gives the best temper. One may even insert some small tools in a lump of ice, as jewellers and watchmakers do when they temper them in sealing-wax. Often oil is used, and it is preferable to water, because it is not so easily evaporated. Everybody knows that damascened blades are tempered in a strong current of cold air, passing through a narrow chink: they obtain thus a temper more uniform than with water. But of all the liquids the most efficacious would no doubt be a metallic liquid, and mercury is the only one extant, being a good conductor of caloric, and always the best of liquid conductors, it appears to be the best bath to be found for the temper of very sharp steel tools. A very good steel, to which in forging it a convenient form should have been given, and which should afterwards have been tempered in mercury, would seem able to cut through almost any substance. Only good care should be taken, in using such process, not to breathe the vapours disengaged from the bath during the tempering. These are purely theoretical considerations, and for the present it is desirable to see them confirmed by practice. *Technologiste, Oct.* 28, 1876.

Sulphuret of Carbon as an Antiseptic.—P. ZOLLER, of Vienna, Austria, has found that in an atmosphere containing some vapour of sulphuret of carbon, generated at ordinary temperature, no further phenomenon of mouldiness or putrefaction is produced. He quite recently reported to the German Chemical Society the result of his experiments as to:—1, the estimation of the minimum of sulphuret of carbon which is to act as an antiseptic in the atmosphere; 2, the way to ascertain if substances preserved by the help of this body may remain comestible. The experiments were made in glass and in zinc vases. The last consist of cylinders 0·70 m. in height on 0·50 m. diameter, provided in their upper part with a sheath set in a cover, and which forms a hydraulic joint. A tube joining the top and the bottom allows the introduction in a vessel of a convenient quantity of sulphuretted vapour. The chemical compound used was as pure as possible, perfectly fluid, and with scarcely any unpleasant smell. It has been ascertained that 20 kilog. of meat contained in one of the vessels were perfectly preserved with 5 grammes of sulphuret. The meat was hanging inside the box, or wrapped up in a towel which had previously been left forty-eight hours in the protecting atmosphere. After three or four weeks, and with a temperature never under 20° C., but which often reached 30° to 33°, the meat was preserved; a small part only of the gravy had run down. The same quantity of sulphuret is sufficient to preserve hot and new bread, vegetables, fruits of all kinds, as well as fruit juices. Five drops of sulphuret in a litre of air destroy any germ of fermentation. Substances preserved in this manner, after having been aërated, may be used as food, and completely resemble the fresh substances in taste as well as in appearance. It has been likewise ascertained that they had no hurtful influence on animal organism. On the opening of the boxes the meat always manifests an unpleasant smell, caused by the sulphuret: this smell decreases by exposition in open air; it completely disappears at the cooking. But it retains an after-taste of volatile fat acid, not unlike that of game rather high. For many consumers that is in nowise unpleasant. From experiments made, it results that the sulphuret of carbon coagulates the white of eggs, and diminishes the quantity of water contained in fresh meat. *Revue Industrielle, Oct.* 18, 1876.

Artificial Ivory.—Two parts of caoutchouc are dissolved in thirty-six parts of chloroform, and the solution is saturated with pure gaseous ammonia. The chloroform is then distilled off at a temperature of 85° C. The residue is mixed with phosphate of lime or carbonate of zinc, pressed into moulds and dried. When phosphate of lime is used the product possesses to a considerable degree the nature and composition of ivory. T. G., in *L'Union Pharmaceutique.*

Note on the Decomposition of a Solution of Iodide of Potassium by Light.—By M. BATTANDIER.—It has often been observed that a solution of iodide of potassium turns yellow under the influence of sunlight, and after a time contains free iodine. According to Vidau this decomposition is due to light alone, and the atmosphere takes no part in the phenomenon. In seeking to verify this statement the author has arrived at a different conclusion.

A ten per cent. solution of pure iodide of potassium was divided into three portions, and exposed (1) to sunlight in the open air, (2) to sunlight in a vacuum, and (3) to the air in the shade. Decomposition took place in No. 1 only. The liquid first turned yellow; then at the end of the third day it gave up to chloroform a small quantity of iodine, which gradually augmented. The experiments were repeated three times, being continued during a fortnight each time, and always with the same result.

These experiments appeared to demonstrate that the intervention of air is necessary to the decomposition. To verify this the same solution was exposed (1) to air and sunlight; (2) to air and sunlight after boiling; (3) to air and sunlight after passing through it a current of pure carbonic acid; (4) to air and light, with a little chloride of barium; (5) to air and light with a little caustic potash; (6) to sunlight and in confined air deprived of carbonic acid by lime; (7) to sunlight and in carbonic acid deprived of air.

In experiments 4, 5, and 6, no appreciable decomposition took place. In experiment 7, on the contrary, it was quite ener-

getic, so that in two hours the solution was already sensibly yellow, and it gradually darkened. In experiment 3, the decomposition was a little less energetic; and still less pronounced in experiments 1 and 2.

From these experiments the author concludes that sunlight and acids present in the atmosphere, and especially carbonic acid, are the principal agents of the decomposition, which results probably from the setting free of a little hydriodic acid.

Vidau found the decomposition to take place in the presence of an excess of caustic potash; this the author would attribute to the action of ozone. He has noticed that his altered solutions possessed marked decolorizing properties—a peculiarity that he has also met with in the iodide decomposed by ozone and in a liquid obtained by saturating a solution of potash with iodine. *Journal de Pharmacie.*

Glycerine in Tanning.—According to the statement of a practical tanner in the *Gerber*, glycerine is specially suited for preserving green skins. By salting they are kept damp, but rendered less useful for various purposes. Carbolic acid preserves them well, but has a tendency to dry them in some measure. All disadvantages may be avoided by treating the skins with a mixture of glycerine and carbolic acid. The carbolic acid increases the preserving effect of the glycerine, while the glycerine keeps the skins perfectly soft and fresh, just as they were directly after slaughter. Both substances are entirely without any injurious action on the substance of the skins, which are freed from them by simply washing, and are then in exactly the same condition for working as ordinary green skins. The fresh skins are covered on the inner side with a mixture of ninety parts of crude dark glycerine and ten parts of carbolic acid, by means of a plasterer's brush, and afterwards treated and packed as usual. It remains to be ascertained by experience whether the advantages of this method are equivalent to the increased cost. For the softening of tanned hides glycerine is not to be recommended; it makes tanned leather stiffer and more brittle than before. Nor is any leather grease containing glycerine of any use, since glycerine is soluble in water.

The Bleaching of Cotton Yarn.—M. L. TOUSSAINT recommends the following method of bleaching cotton yarn:—Let 220 lbs. of cotton yarn be bucked for eight hours in a soda lye composed of 6¼ lbs. of crystallized soda and 2¼ lbs. of slaked lime. After being steeped in the bucking caldron and washed, the yarn is put into a solution of chloride of lime; remains there two hours, and goes direct thence to the diluted sulphuric acid, in which it remains for twenty minutes. The above-mentioned quantity of yarn requires 11 lbs. of chloride of lime powdered, and 1⅛ part of sulphuric acid.

After the bleaching, the yarn should be carefully washed in flowing water, and then put—sometimes twice—into a soap bath containing 1 kilogramme (2·2 lbs.) of palm-oil soap for every 100 kilogrammes (220 lbs.) of yarn. By this means the cotton is freed from the adhering acid, and can now be sized—warp yarn with 6 kilogrammes (13·2 lbs.) and woof yarn with 2 kilogrammes (4·4 lbs.) of starch for every 100 kilogrammes (220 lbs.), with the addition of some acid-proof ultramarine. Cotton yarn so treated is quite uniformly bleached, and continues beautifully white in the warehouse, whether in skeins or textures. *Moniteur Industriel Belge.*

Gas from Naphtha.—Various attempts have been made to find some substitute for coal as a source of lighting-gas. It has been obtained from wood, and by distillation from heavy oils, as petroleum, tar, &c. It would now seem that means have been found for making it from naphtha. Important experiments have been made, from which it appears that the cost of manufacturing it from this source would scarcely amount to one-fourth of that of ordinary coal gas. *Abridged from the Technologiste.*

Discovery of Falsification in Writing.—Herr GOBERT has found that if writing is ever so carefully scratched out, there are still left sufficient traces of the oxide of iron in the ink to become visible in a photographic copy. Light reflected from paper that has not been written on acts in a different way on the photographic materials from that reflected from places which have been once covered with ink. By this means the genuineness or otherwise of a document can always be ascertained. *Stummer's Ingenieur.*

A Remedy for Worm-eaten Wood.—As a means of destroying the worms which make holes in wood, M. E. LAVEZZARI has found a mixture of carbolic acid and essence of turpentine effectual. He recommends that a small bottle, containing about an ounce, should be filled with equal quantities of each, and the mixture applied carefully to every hole with a hair brush. It is indispensable that not a single hole should be omitted, otherwise there is no certainty of success. The insects will be seen to come out of the hole and die immediately, even before they are directly attacked, owing to the penetration of the liquid through the wood near them.

Nitrate of Ammonia.—The "Teinturier Pratique" points out a new method of preparing this salt, which consists in mixing a solution of nitrate of soda or potass in suitable proportions, with a solution of carbonate of ammonia, and saturating the mixture with carbonic acid. The nitrate of ammonia, being more soluble, is dissolved, and the bicarbonate is precipitated.

Practical Literature.

THE IRON AND METAL TRADES' COMPANION.[1]

A NEW kind of ready reckoner, especially fitted for trades whose dealings are in weights. The title page sufficiently indicates the scope of this exceedingly useful manual, the application of which is very simple. Taking a given price per cwt. or per pound, a glance is sufficient to find the price per pound from 1 to 27 lbs., per quarter, and per cwt. from 1 to 2,000 cwts. It will thus be seen that this handy work is of equal value and interest to other trades than those to which it appeals in its title.

INDUSTRIAL CONCILIATION.[2]

AT a time when the relative positions of capital and labour are undergoing such important modifications, and when the struggle between employers and their workmen has assumed such gigantic dimensions, the publication of this work is extremely opportune.

As its name implies, it is a plea, and a very powerful one, too, for the universal establishment of "boards of conciliation," consisting of an equal number of employers and workmen, by which all disputes between them may be amicably arranged and strikes and lock-outs prevented. Boards of this kind, as is well known, have been established in the hosiery, lace, iron and coal trades, and have, on the whole, been highly successful, causing cordiality and mutual respect to give place to suspicion and distrust. There certainly seems no reason why what has succeeded so well in these trades should not succeed equally well elsewhere, and it is to be hoped that the experiment may be tried ere long, and may be successful. As the author of this work justly observes, this can only result where implicit loyalty to the board and to its decisions is maintained by both sides, and this is undoubtedly the main difficulty to be overcome, a difficulty, however, which is rapidly lessening under the influence of education and superior enlightenment.

While by no means sharing in the distrust of trades-unions which is even yet rife, we cannot but think that the picture which Mr. Crompton draws of them in his book is by far too flattering. That workmen have a perfect right, both legal and moral, to combine for their mutual protection against the

[1] *The Iron and Metal Trades' Companion: being a calculator containing a series of tables upon a new and comprehensive plan for expeditiously ascertaining the value of any goods bought or sold by weight, from one shilling per cwt. to* 112*s. per cwt., and from one farthing per pound to one shilling per pound. Each table extends from one pound to* 100 *tons. To which is appended rules on decimals, square and cube root, mensuration of superficies and solids, &c., also tables of weights of materials and other useful memoranda.* By Thomas Downie. London: Crosby, Lockwood and Co. 1877.

[2] *Industrial Conciliation.* By Henry Crompton. Henry S. King and Co. 1876.

encroachments of capital is an axiom which only the most ignorant and prejudiced will dispute, and there can be as little doubt that the principles upon which trades-unions were originally founded are both just and right. It is, however, unfortunately too true, that they have in many instances degenerated from those principles, and, not satisfied with asserting and securing the liberty and independence of their members, are endeavouring to substitute for a tyranny of capital a yet more odious tyranny of labour. The unionist has yet to learn that the same liberty, which he adduces as his right, to enter into combination with his fellows, is equally the birthright of his brother workman who may choose to stand aloof, and that when he attempts to coerce the latter into the acceptance of his views by the application of force in any form he is violating in the grossest manner that very charter of which he himself so proudly boasts. When we see unionists supporting their fellows in the violation of just and necessary laws, and attempting to raise to the dignity of martyrs those who have justly suffered for actions which are both legally and morally wrong, we cannot but feel that there is yet much which the British workman has to learn with regard to his true position with reference to this important question.

Never was there a time in which there was more necessity for complete harmony between capital and labour in this country than the present, and it is to be earnestly hoped that both one and the other may speedily recognize their true position. To all who are concerned in this momentous question we most heartily recommend a perusal of Mr. Crompton's book, feeling assured that they will receive from it much information, and a firm conviction of the responsibilities resting upon men of business.

PRACTICAL TUNNELLING.[1]

IT is now some years since the monograph from the pen of Mr. Frederick Walter Simms, which forms the basis of the handsome volume which now lies before us, first appeared, and we believe it is no exaggeration to say that it has taken its place among the classics of our "Practical Literature." As most of our readers who are interested in such matters are doubtless aware, it originally consisted of an elaborate account of the construction of the Bletchingley and the Saltwood tunnels on the South-Eastern Railway; and, to use the words of the editor of the present edition, it "comprises a thoroughly practical description of the work at every stage of its progress, and presents in a typical form the ordinary routine and experience of tunnelling in clay and in sand."

This work of Mr. Simms still stands unrivalled, and is as useful at the present day as it was when it was first published. A mere enumeration of the contents of the chapters in the original work will suffice to show how thoroughly the subject was exhausted by him. Every detail being filled in with the most scrupulous exactness and care, and every particular necessary to guide future workers being explained with the minutest accuracy, while the principles which must govern the execution of such works are laid down with a breadth which, considering the comparatively limited extent to which such operations were carried in those earlier days of railway enterprise, is simply astounding.

The geological features of the railway on which the tunnels in question were made are first discussed, and a general description and statement of the dimensions of the tunnel is given. Then follow descriptions of the observatory, the transit instrument, and the methods of fixing and adjusting it, the plan adopted for laying out the tunnel being generally described in this chapter. Chapter III. treats of setting out the shafts, ranging the line above and below ground, taking the levels, and establishing bench marks or points of reference, &c. Chapters IV., V., and VI. deal with shaft-sinking, and the details of work connected therewith. Then follows a chapter on driving the headings, and chapters VIII. to XI. are devoted to the description of the actual construction of the tunnel. Tunnel entrances, shaft towers, culvert through the tunnel, are next dealt with, and the thirteenth and last chapter describes the centres of ordinary construction and Fraser's patent centres.

This, then, is a rough outline of the contents of the work as it originally stood; but since the Bletchingley and Saltwood tunnels were constructed much new experience in tunnelling has been gained; "for many other tunnels have been constructed under different circumstances, and through ground of various geological construction. Other types of construction have been developed, of which it is scarcely necessary to state that the tunnel under the Col de Frèjus, commonly known as the Mont Cenis Tunnel, above 7½ miles in length, is the greatest and most wonderful achievement of the time." There is also the unique construction of our Underground Railways in London, to say nothing of many other important tunnelling works which have been undertaken and carried to a successful issue in recent years. In fact, to quote Mr. Kinnear Clark's words: "Every tunnel has its own peculiar history in execution; difficulties are continually occurring which cannot be seen in the estimates; contingencies are met with which require all the resources of mechanical science and all the experience and enterprise of engineers and contractors to bring to a successful issue."

Recognizing these important facts, and desirous that Simms' invaluable work should not lose the position it occupied in our practical literature, the publishers have with commendable enterprise, aided by Mr. D. Kinnear Clark and Mr. W. D. Haskoll, prepared and issued this new and very considerably enlarged edition, in which the text of the original work is substantially retained in matter and in form, while such additional chapters as are necessary to bring the work up to our present knowledge of the subject have been added. The only departure from the original plan of the work is, we believe, the drafting off and collecting into a special chapter the statistical matter bearing upon labour, wages, materials, and cost of construction, which was in the previous edition scattered throughout the text. A change which we think adds much to the usefulness of the book as making these points more easy of reference.

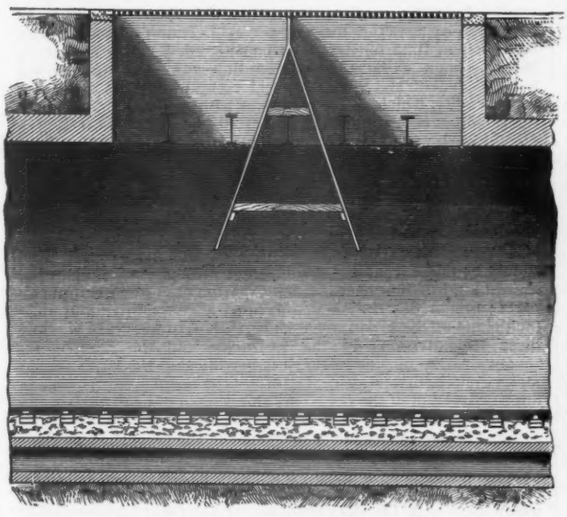
An excellent paper by Mr. Clark, consisting of an historical view of tunnelling and a general description of the method of procedure and tunnelling with especial reference to our more modern appliances, and embracing some of the results of our more recent experience, forms an appropriate introductory chapter to the original text. Mr. W. D. Haskoll, who edited the second edition of the work, adds some useful notes to chapters I., III., IV., V., and VI., pointing out in one of them that shafts may under certain conditions be entirely timbered from top to bottom, with great strength and considerable saving of labour, instead of being all constructed of brickwork. Mr. Haskoll also contributes a chapter on tunnels and tunnel entrances, referring especially to those on the Wilts, Somerset, and Weymouth, the South Wales, the Manchester, and Leeds railways, and to the Birkenhead Tunnel.

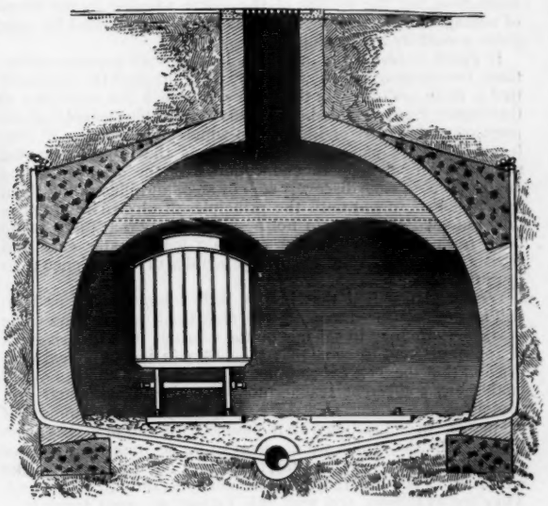
The additional chapters on the more recent practice of tunnelling by Mr. D. Kinnear Clark are of especial importance and value, but it is impossible for us to do more than indicate the chief features. The various systems of the driving of tunnels in this and in other countries, at different periods and under varying circumstances, are first treated of, especially those known on the continent as the English-Belgian systems, based on the top heading and the bottom heading respectively. A chapter then follows on Casualties in Tunnelling: a subject which as the author says is full of interest and of usefulness to those "who have to grapple with the unforeseen," and this chapter shows that in tunnelling, as in many other things, the chapter of accidents always has a very large space devoted to it. Tunnelling in clay, marl, through coal measures and in hard rock, is next discussed, and illustrated by the description of works prosecuted in various parts of the country. A chapter is then devoted to the enlargement of tunnels, an operation which, owing to the special difficulties in the way, we should not be surprised at any engineer shrinking from; such works are, however, happily of rare occurrence, as most tunnels have been constructed for at least two lines of rails. This chapter is followed by three chapters on the important subject of tunnelling in hard rock, the last two of them dealing with those marvels of modern engineering enterprise—the Mont Cenis and St. Gothard Tunnels. But of these we have left ourselves but little space to speak. The particulars of the construction of the former will doubtless be fresh in the minds of those interested in the subject, and if they wish to refresh their memory they cannot do better than go to Mr. Clark's chapter for this purpose, the details of which are chiefly derived from two papers read by Mr. Thomas Sopwith before the Institution of Civil Engineers. Considerable space

[1] *Practical Tunnelling: explaining in detail the Setting out of the Works, Shaft-Sinking and Heading-Driving, Ranging the Lines, and Levelling Under Ground, Sub-Excavating, Timbering, and the Construction of the Brickwork of Tunnels, with the amount of Labour required for and the Cost of the various portions of the Work.* By Frederick Walter Simms, C.E., author of "The Public Works of Great Britain," "A Treatise on the Principal Mathematical Instruments Employed in Surveying, Levelling, and Astronomy, &c." Third Edition. Revised and Extended, with additional chapters illustrating the recent practice of Tunnelling, as exemplified by the St. Gothard, Mont Cenis, and other modern works. By D. Kinnear Clark, M. Inst. C.E. London: Crosby, Lockwood, & Co. 1877.

has also been devoted to an account of the St. Gothard Tunnel, the materials for which have "for the most part been drawn from the excellently prepared quarterly reports of the 'Engineer.'" The general subject of the cost of tunnels is dealt with in a chapter by itself, and it is interesting to note that while for the ordinary gauge of railways, with a double line of way, the cost of tunnelling under the most favourable conditions may be as low as £20 per lineal yard, under a combination of unfavourable circumstances it has been as high as £125 per yard. The Thames Tunnel cost £1,137 per lineal yard.

Within the past few years a new factor has presented itself in tunnel engineering, owing to the enormous increase of traffic and the great length of tunnels; and the task of solving the problem of how to secure efficient ventilation for tunnels has of late been taxing the ingenuity of our engineers. There are few Londoners who have not experienced the unpleasant effects of the accumulation of impure air when travelling on the Underground Railway—effects which gained for the line in its earlier days the *sobriquet* of "the sewer." When the line was first opened it was quickly found that the natural ventilation in certain sections was totally inadequate, and it became necessary to make special provision for it; additional openings were made and existing ones were enlarged; but as the traffic increased, even these were found to be deficient; observations were made, experiments of various kinds were tried, but without effect, until at length Mr. Tomlinson, the resident engineer, devised a plan, which, with certain modifications according to the special circumstances, bids fair to meet all the requirements for the efficient ventilation of tunnels. He "proposed to intercept the current [of smoke and fume] at the openings by fixing diaphragms across the upper part of the tunnel, clear of the trains, and so cause at least a portion, more or less, of the current to be expelled by the piston-like force of the trains." This contrivance, which by the courtesy of the publishers, we are enabled to illustrate in the figures given herewith, showing tranverse and longitudinal sections of the tunnel with the diaphragms, "was applied at thirteen points in the tunnel between Edgeware Road and King's Cross; the results were good, for the atmosphere of the tunnel was decidedly improved. Besides driving out the foul air the train as it passed onwards drew after it a very strong current of external air into the tunnel. The force of this current gradually decreased until the train had reached the next opening. The alternate upward and downward currents were generated at each opening on the passage of a train. A great improvement also was effected at the stations: before the screens were erected each train that arrived at a station was followed by a current of foul air; but now it was to a great extent intercepted and shunted by the screen into the upper air." This plan, although limited





in its scope of action, is the one that has been attended with the best practical results, and there is no doubt that the application of the principle will become universal wherever artificial ventilation is required. With certain modifications it is applicable alike to short tunnels near the surface of the ground where the traffic is very frequent, as in the case of the Metropolitan Railway, in which there are permanent open shafts from the tunnel to the surface, and to tunnels of great length open only at the ends. The modifications of the principle by which the latter kind of tunnel may be ventilated have been proposed by Messrs. W. H. Barlow, Longridge and V. G. Bell, and the system has been designated the "separate system," the simplest application of which, our author says, "consists in the employment of an upper chamber or driftway, formed in the upper part of the tunnel by a horizontal brattice, extending from one end of the tunnel to the other, into which the gases and steam are discharged, direct from the chimney of the locomotive, through longitudinal apertures. Let an additional interior horizontal brattice be erected, but without any vertical diaphragms. The upper brattice will then enclose a free driftway, which may be assumed to be a circular segment, 5½ feet high and 20 ft. wide at the level of the brattice, with a clear sectional area of 60 ft. Let numerous openings be formed in the upper brattice, for the transmission of the gases from the interspace into the driftway. Thus, the gases so separated from the atmospheric air of the tunnel can be withdrawn by exhausting machinery placed at each end of the tunnel. On this system the tunnel would be ventilated from the middle towards the ends. The areas of the openings through the upper brattice would require to be adjusted, so that the ondraught, at all points of the tunnel, should be just sufficient directly to withdraw the gaseous discharge into the interspaces; "for the attainment of such uniform suctional action, the allowance of passage way through the upper brattice per yard run of the tunnel should be a maximum at the middle of the tunnel, where the suction force is weakest, and a minimum at each end, where the suctional force is greatest, being properly graduated between the middle and the ends." After comparing this plan with others that have been suggested or tried, our author comes to the conclusion that "the power necessary to ventilate the tunnel by a brattice driftway, on the separate system, is an infinitesimal portion of that which is required to ventilate through the entire sectional area of the tunnel. Conclusive evidence is afforded that the separate system of ventilation is to be the method of the future. It affords a complete solution of the problem of the perfect and economical ventilation of the Metropolitan Railway in potentiality and economy of outlay, far surpassing any natural system of ventilation. Likewise, and with equal facility, it affords a complete solution of the problem of the ventilation of the projected Channel tunnel, twenty-two miles in length."

Our description of this important work must close here, and it only remains for us to remark on the care and completeness with which the work has been turned out. A glossary of the more specially technical terms used is printed at the end of the book, and a good index is given. The illustrations and diagrams are profuse, and, as the examples here given will show, are models of clearness. Editor and publisher alike have done their work in a manner which leaves nothing to be desired, and the profession is to be congratulated upon the publication of this third edition of Simms' "Practical Tunnelling."

LESSONS IN ELECTRICITY.[1]

WHATEVER place Professor Tyndall may occupy in the estimation of posterity as a scientific investigator and discoverer, there can be no doubt that his name will long be known as one of the most, if not the most, lucid and brilliant of all scientific expositors of the present period; and this is no mean distinction in a day like this, when the cultivation of this faculty is so earnestly prosecuted by men who are most eminent in every branch of knowledge.

Two of Professor Tyndall's works have always seemed to us to be especially perfect as models of clear exposition, penned in a style which, while bringing unmistakably before the reader's mind the facts and principles of the subject under discussion, gave it an interest that was almost fascinating; containing not one superfluous word, not one superabundant illustration, and yet not erring on the side of meagreness in either. We refer to "The Forms of Water" and "The Notes on Light." To these he has now added a third, in the shape of these "Lessons in Electricity," which, like the first of the books mentioned, contains the substance of a series of Christmas lessons given at the Royal Institution to an audience of boys and girls. These Christmas lectures have, since 1829, formed a special feature of the Royal Institution, and the wisdom of the course adopted by the board of managers in instituting them has been fully attested by their great popularity and usefulness.

It would, naturally, be in vain to look, in such a course of lectures, for anything very new in the matter, although there is much that is fresh and novel in the manner in which the principles of the science are expounded. With that admirable clearness of expression and felicity of illustration which characterizes all Professor Tyndall's expositions, he conducts the learner from the simple historical facts in connection with the science, tracing and explaining each discovery step by step, and illustrating them by ample experiment until the principles of electricity are thus fully unfolded; and we do not hesitate to say that there is no book from which the learner can gain with greater ease and pleasure a knowledge of the first principles of the science than from this one.

We are glad to find that in this little volume Professor Tyndall has endeavoured to meet the objections urged to the value of science-teaching in schools on the score of the expensiveness of apparatus, and to show that the obstacle is not a real one, proving that the wise expenditure of a couple of guineas would enable any competent teacher to place the leading facts and principles of frictional electricity completely at the command of his pupils. In connection with this subject, the author makes some further remarks, which we consider to be so important that we should like every schoolmaster, and every one interested in the education of our children, to have them constantly in their mind. They are as follows, and with this extract we must leave Professor Tyndall's most valuable and instructive little book:—"I would urge upon the science teachers of our public and other schools, that the immediate future of science as a factor in English education depends mainly upon them. I would respectfully submit to them whether it would not be a mistake to direct their attention at present to the collection of costly apparatus. Their principal function just now is to arouse a love for scientific study. This is best done by the exhibition of the needful facts and principles with the simplest possible appliances, and by bringing their pupils into contact with actual experimental work. The very time and thought spent in devising such simple instruments will give the teacher himself a grasp and mastery of his subject which he could not otherwise obtain; but it ought to be known by the head masters of our schools that time is needed not only for devising such instruments, but also for preparing the experiments to be made with them after they have been devised. No science teacher is fit to meet his class without this distinct and special preparation before every lesson. His experiments are part and parcel of his language, and they ought to be as strict in logic, and as free from stammering as his spoken words. To make them so may imply an expenditure of time which few head masters now contemplate; but it is a necessary expenditure, and they will act wisely in making provision for it. To them, moreover, in words of friendly warning, I would say, make room for science by your own healthy and spontaneous action, and do not wait until it is forced upon you by revolutionary pressure from without."

[1] *Lessons in Electricity at the Royal Institution*, 1875-6. By John Tyndall, D.C.L., LL.D., F.R.S., &c., &c. London: Longmans, Green, and Co. 1876.

PHYSICAL MANIPULATION.[1]

DURING the past few years there has grown up not only a large band of scientific teachers and a still larger army of students, but an almost entirely new method of teaching science—a method which, we are convinced—and all who are engaged in the work of teaching will corroborate our statement—is the only one which can be expected to yield any really beneficial results. The system of lecturing to students, performing experiments, making practical demonstrations, &c., while it must in some cases be retained as absolutely necessary, is fast giving way to what may be called the practical method of teaching, whereby every student performs for himself the experiments which demonstrate the principles of the science he is studying, and in many instances has to construct the simpler forms of apparatus which are needed for this purpose. The value of such a method, and its superiority over the mere witnessing of experiments, no matter how brilliantly performed or how lucidly explained, must be evident. It gives to the student a new interest in connection with his studies, and besides its immediate effect upon them, develops a practical skill which cannot fail to be of value. If it be urged that it occupies too much of the student's time, we reply that the knowledge gained by practical experiment is far more permanent and thorough than that which can be gained by any other method of teaching; and if thoroughness be aimed at time must not be considered, for it is manifestly better to know six facts of a science thoroughly than to have but a hazy idea of sixty, and we feel certain that the charge of superficiality, which is often so justly brought against much of the scientific education of the day, would be disproved if experimental work were more universally enforced in our schools and science classes.

These reflections have been provoked by an inspection of the work of which the title is quoted at the head of this notice—a work which cannot fail to prove of immense value to all engaged in scientific education. Its object is to describe the principal methods of experiment, with which every physicist should be familiar, and it includes not only physics proper, but several kindred branches. Each experiment is divided into two parts: first, a description of the apparatus required, and then the details of the experiment. The author, in his preface, allots these two divisions to the instructor and the student respectively. In our judgment, it is needful that the latter should make them both his own, and of course there is no reason in the construction of the book why this should not be done.

The subjects dealt with are, first, electricity heat, as being perhaps better adapted than any other to the laboratory system; then mechanical engineering, meteorology, and astronomy; a chapter is added on lantern projections, which cannot fail to be of great use to the lecturer on science, and appendices are given which deal with (*a*) the principles of electrical measurements under the title of the theory of electrical phenomena, (*b*) a series of tables of the numerical constants most used in physical work, and (*c*) some detailed directions for the establishment of physical laboratories. That the plan of the work may be rendered more complete a list of works of reference, about one hundred additional miscellaneous experiments, and last but not least, a copious and carefully prepared index are given.

The experiments detailed in the section entitled "Mechanical Engineering," throughout of the most advanced or highly complex kind, are those which are important to every physicist, inasmuch as "Physical problems which are to be solved on a large scale require a knowledge of mechanical engineering." Under this head such questions are dealt with as piping, steam boilers and the steam-engine, efficiency of boilers, covering steam-pipes, testing gauges, pressure and temperature of steam, indicator diagrams, friction brake, transmission dynamometer, speed of piston rods, fly-wheels, and shafting, strength of materials, and friction of belts and pulleys.

We have not seen the first part of the work, but from the volume before us we have formed a very favourable opinion of its value, especially to all who are interested in laboratory work and in science teaching. As an aid to independent scientific research, the work will be most useful, and we feel confident that the book will be as well appreciated here as we doubt not it already is in the country of its origin.

[1] *Elements of Physical Manipulation.* By Edward C. Pickering, Thayer Professor of Physics in the Massachusetts Institute of Technology. Part II. London: Macmillan and Co. 1876.

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